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Use of Climatic Data in Estimating Storage Days for Soils Treatment Systems

National Climatic Center, Asheville, N C

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EPA-600/2-76-250
November 1976

USE OF CLIMATIC DATA IN ESTIMATING STORAGE DAYS FOR
SOILS TREATMENT SYSTEMS

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ABSTRACT

The number of days each year that Soils Treatment Systems may be inoperative because of unfavorable weather conditions can be estimated from analysis of daily climatological data. In cold regions each winter season (Nov.-Apr.) is examined for a 20- to 25-year period. Each day is defined as favorable, partly favorable or unfavorable using a set of thresholds for temperature, precipitation and snow depth. A daily accounting procedure adjusts the increase or decrease in storage on the basis of the type of day and the drawdown rate. The maximum storage days each year are summarized in a final table which also presents the mean, the standard deviation, the unbiased third moment about the mean, the coefficient of skewness and storage days for recurrence intervals of 5, 10, 25 & 50 years.

A separate program is used for stations in wet regions where the primary constraint to land application is saturated soil. The daily mean temperature and precipitation are examined for a 20- to 25-year period using the modified Palmer program. This program estimates the condition of both the underlying and surface soil layers in an attempt to identify periods when saturation occurs and runoff would result from additional precipitation or application. The longest consecutive period of unfavorable days each year is summarized in a table that also shows estimated storage days at the 5, 10, 25 & 50th percentiles.

Chronological listings of the actual data and computations for the entire period of record can also be furnished. Thresholds of most of the parameters can be changed to suit individual systems. The program can also be modified to examine the condition of the surface layer during the growing season as an estimate of irrigation needs.

This report is submitted in fulfillment of Interagency Agreement EPA-IAG-D5-F694 by the National Climatic Center, Asheville, North Carolina. Work was completed on June 30, 1976.

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CONVERSION TABLES

ENGLISH TO METRIC UNITS

Length:

- 1 inch (in.) = 25.4 millimeter (mm.)
= 2.54 centimeter (cm.)
- 1 foot (ft.) = 30.48 centimeter (cm.)
= 0.3048 meter (m.)
- 1 yard (yd.) = 91.44 centimeter (cm.)
= 0.9144 meter (m.)
- 1 statute mile (stat. mi.) = 1609.344 meter (m.)
= 1.609344 kilometer (km.)

Speed:

- 1 mile per hour (mi. hr.⁻¹, mph) = 0.868391 knot (kt.)
= 0.44704 m. sec.⁻¹
= 1.609344 km. hr.⁻¹

Density, Specific Volume:

- 1 pound per cubic foot (lb.ft.⁻³) = 0.0160185 grams
per cubic centimeter (g.cm.⁻³)

Pressure:

- 1 standard atmosphere (14.7 lbs. in.⁻²) = 760 millimeters of
mercury (mm.Hg.)
- 1 millibar (mb.) = 0.750062 millimeters of mercury (mm.Hg.)

Temperature:

- Celsius (C) = $\frac{5}{9}(F-32)$ where F is temperature in degrees
Fahrenheit
- Absolute (A) or Kelvin (K) = C + 273.16

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Special recognition is extended to Dr. J. R. Mather, Wayne C. Palmer and others for their work in developing many of the techniques used in these programs. The concept of assessing the water balance in the general manner described was developed by the late C. W. Thornthwaite.

SECTION 1

CONCLUSIONS

Engineers, planners, and designers of Soils Treatment Systems may need an estimate of the number of days when land application would be undesirable due to certain weather conditions. If storage must be planned during extended periods when application would result in surface runoff, the programs developed can be used to estimate the duration of such conditions. In addition, the modified Palmer program (EPA-2) might be useful in estimating irrigation needs during the growing season.

The programs developed by the National Climatic Center, through support of the Environmental Protection Agency, provide estimates of storage requirements using 20 to 30 years of daily climatological data. Two of them (EPA-1 and EPA-3) are designed for use at stations in cold regions, while another (EPA-2) is best suited to those in wet regions. The EPA-3 program is similar to EPA-1 but examines daily maximum and minimum temperatures instead of the daily mean temperature. In this program an unfavorable (UNF) day is defined as one with precipitation of one-half inch or more, snow depth one inch or more, or a maximum temperature less than 40°F. A favorable (FAV) day is one with less than one-half inch precipitation, snow depth less than one inch, a maximum temperature of 40°F or more and a minimum temperature of 25°F or more. Partly favorable (L) days have less than one-half inch precipitation, less than one inch of snow on the ground, maximum temperatures of 40°F or more, but with minimum temperatures less than 25°F. On FAV days the decrease in storage is equal to the daily flow (Q) minus the drawdown rate (DD). On 'L' days, the increase (gain) in storage is equal to $Q - (DD/2)$, while on UNF days the increase in storage is equal to Q.

A final summary of EPA-3 includes the yearly storage values from which the mean, standard deviation and other statistics are derived. Finally, the estimated storage days are computed by the Pearson Type III method for recurrence intervals of 5, 10, 25 and 50 years.

The programs represent a rather simple approach to a complex problem. (They deal almost exclusively with climatological factors rather than biologic or hydrologic ones. In spite of the great variability in soils, climate and waste characteristics, reasonable estimates of storage requirements due to climate can be obtained from daily climatological records.

Estimates derived from these programs should be examined carefully to determine if adjustments are necessary because of local conditions. No program can account for all possible variables such as the quality and concentration of the effluent, depth to water table, soil type and condition, loading rates and others.

Hill [1] points out that the Thornthwaite method for estimating evapotranspiration from the mean daily temperature and length of day is generally conceded to be a poor estimator for daily amounts. However, it appears that in identifying wet spells neither evapotranspiration nor the available water capacity of the soil significantly affects the results; that is, when rainy spells occur, the amount of rainfall is sufficient to saturate the soil regardless of its assigned capacity.

Estimates from EPA-2 based on 25 years of record for stations in wet regions do not always fit a smooth pattern. Estimates range from 11 to 35 days in Louisiana, 12 to 33 days in Mississippi and 21 to 165 days in Oregon. The greatest number of storage days due to saturated soil occurs along the coast of Washington and Oregon.

A modification of EPA-2 examines the runoff and the condition of the surface and underlying soil in defining unfavorable days. Additional modification might be advisable in order to classify days as unfavorable unless the computed soil moisture is lower than the proposed loading rate. There are times when runoff is not indicated yet the underlying layer (SU) is saturated and the surface layer (SS) is within a few hundredths of an inch of being saturated. The program can be altered to class such days as unfavorable. This feature is identified on the listing by a percent following the EPA-2 indicator; for example, EPA-2(10%) denotes a set of data processed using not only the runoff feature in defining unfavorable days, but includes those days when the sum of the surface (SS) and underlying (SU) layers is within the indicated percent (10) of saturation. Of course, saturation is defined as the assigned available water capacity (AWC) for that location. This feature has the effect of extending the wet spells between a series of days with runoff. It can also be useful in estimating irrigation needs during the growing season since the moisture in the surface layer is indicative of the amount available in the root zone. It should also prove useful in estimating, along with other factors, the maximum loading rate during certain times of the year.

Finally, the variability in the amount of storage needed from year-to-year can be significant at some stations. For example, standard deviations of 15 to 20 are common at stations having a mean of 45 storage days. The yearly storage values can be used as input to the Gumbel extreme value analysis which gives estimates of storage days for return periods up to 100 years with confidence bands of $\pm 34\%$.

SECTION II

RECOMMENDATIONS

The programs defined as P03B75:NCC-EPA-1 or EPA-3 generally should be considered at sites where the normal January temperature is colder than 40°F (4.4°C), while SOILMT:NCC-EPA-2 should be used in areas where the normal annual precipitation is 50.00 inches (1266 mm) or more. The selection of these arbitrary thresholds was made after processing a number of stations on both programs. The transition zones are not clearly defined and the 40°F temperature and the 50 inches of precipitation are only rough approximations. It may be desirable in some cases to process the data both ways, especially in the Pacific Northwest.

Each program was developed to accept variable thresholds which can be changed to account for differences in soils, systems, etc.; however, the basic programs remain intact. Sharp differences in temperature, precipitation, and soil can occur over very short distances, hence each site should be examined on an individual basis. Consultation with hydrologists, geologists, soil scientists, and other specialists is highly recommended.

SECTION III

INTRODUCTION

A need was expressed in 1974 by the Robert S. Kerr Environmental Research Laboratory, Environmental Protection Agency, to find a way of using climatic data to estimate storage days for Soils Treatment Systems. Some thought was given to using soil temperature and soil moisture measurements, but this was not possible because of the paucity of data. The programs developed at the National Climatic Center (NCC) require serially complete, long-term digitized data. This type of daily climatological data is available for many locations in the NCC's tape library.

Once the data base had been selected, it was necessary to determine just what constituted climatic constraints to land application. It soon became apparent that a constraint for one system and location often was not a constraint elsewhere. In addition, while cold and snow might be definite constraints in some regions, prolonged rainy spells would be the major deterrent in others. Add to these variables the different types of soils, systems, types of effluents, etc. and one can sense the misgivings with which this project was started.

There were one or two hopeful signs. First, if the user can specify the types of weather unfavorable for a particular operation, those days can be identified. Second, Palmer's program [2] to identify droughts might be modified to define days when the soil was saturated and runoff would occur. The development of these programs provided a method of estimating storage days in cold and in wet regions. Only experience and observation will reveal how well these programs work. No field tests or controlled studies have been made; however, continued alterations are being made to the programs.

Each program can accept variable input, i.e. different thresholds, in order to be of maximum use. The basic programs remain standard, while the adjustment factors can be changed to account for the variations in soils, systems and climate. As a first approximation these programs are being used with a set of threshold values which are applicable for wastewater irrigation systems. Thresholds applicable for high-rate infiltration systems and overland-flow systems will be developed later.

The U. S. Army Corps of Engineers has done a vast amount of research in connection with soil trafficability. Much of their investigative work [3] is geared toward developing programs that can predict the state of

the soil at a given time and place. Other efforts have been centered on the prediction of stream flow and with the hydrologic quality of soils [4]. Nothing in the literature examined dealt with the problem of identifying the frequency or duration of periods when the ground was saturated, although a number of studies [5-12] examined the water balance during the growing season.

The soil type and its condition more than any other factors generally determine the amount of runoff. The Soil Conservation Service (SCS) has completed surveys in many areas and has published detailed information for various soil series that may be obtained at local SCS offices [13].

Although the available water capacity (AWC) may not be a major factor in the programs discussed, it is an important soil property for other reasons. It is often given in reports as estimated amounts of water, in inches per inch of soil for specific soil layers. The following adjective ratings refer to the sum total of available water from the surface to bedrock, or to a depth of 60 inches.

Very Low	< 3 Inches
Low	3 to 6 Inches
Medium	6 to 9 Inches
High	9 to 12 Inches
Very High	> 12 Inches

The four major hydrologic soil groups, as described by the Soil Conservation Service, are presented here for information.

A. (Low runoff potential). Soils having high infiltration rates even when thoroughly wetted. These consist chiefly of deep, well to excessively drained sands or gravels. These soils have a high rate of water transmission in that water readily passes through them.

B. Soils having moderate infiltration rates when thoroughly wetted. These consist chiefly of moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission.

C. Soils having slow infiltration rates when thoroughly wetted. These consist chiefly of soils with a layer that impedes downward movement of water or soils with moderately fine to fine texture. These soils have a slow rate of water transmission.

D. (High runoff potential). Soils having very slow infiltration rates when thoroughly wetted. These consist chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface, and shallow soils over nearly impervious material. These soils have a very slow rate of water transmission.

The programs developed at the NCC appear to follow actual physical processes rather well, at least as far as climatology is concerned. The depletion rate in EPA-2 was introduced to offset a unique condition in Palmer's original program. It can best be explained by saying that his weekly and monthly accounting systems had no provision to carry-over runoff. In the daily accounting, it became necessary to gradually deplete the excess defined as runoff. Since only a percentage of the surplus water runs off on any day [13], it was necessary to assign some estimated amount to account for gravitational water that is made available as runoff in the following days. The amount lost each day depends on, among other things, soil type, structure, and depth of the soil layer.

It became clear that any attempt to introduce all of the variables affecting storage was either not possible, or not justified on the grounds of time and money. An empirical approach seemed to offer a reasonable escape from this dilemma. Stations with different soil groups (clay, loam, and sand) were processed using assigned depletion rates (.50, .75, and 1.00 inch per day, respectively). The only guide used in selecting these numbers came from experience and observation. For example, if the indicated amounts fall on saturated soil it will very likely take at least one day for that particular soil to dry enough so that application is possible. The programs discussed in this report use limited input data in an attempt to attain certain objectives. Most of the development discussed in the report focuses on irrigation-type systems whose operation is influenced much more by precipitation than by either overland-flow systems or high-rate infiltration systems.

One of the obvious limitations in this report is in the area of hydrology. None of the programs discussed in this report provide information dealing with the intensity, duration or amount of precipitation from individual storms. The Office of Hydrology, National Weather Service has prepared precipitation frequency analyses for all locations in the United States [14, 15, 16]. Publications are available with generalized charts from which the magnitude of 10-year 24-hour and 25-year 24-hour precipitation amounts can be obtained for any location. Information about the areal variability of rainfall, recurrence intervals, as well as information on evaporation should be requested from that office. Other offices to be contacted for related information include the U. S. Geological Survey, the U. S. Army Corps of Engineers and the U. S. Department of Agriculture's Soil Conservation Service.

SECTION IV

ESTIMATING STORAGE CAPACITY IN COLD REGIONS

If a Soils Treatment System is designed to operate during the winter months in regions where the normal January temperature is colder than about 40°F (4.4°C), storage needs can be estimated by converting days defined as unfavorable into days of storage using either the EPA-1 or EPA-3 program. Temperature, snow depth, and precipitation are examined each day during the months of November through April for a period of 20 to 25 years. The exact period depends on the completeness and length of the digital record for the particular station.

The EPA-1 program [17] defines each day as favorable or unfavorable for operation on the basis of the assigned thresholds. While these thresholds can be varied, almost all stations processed on EPA-1 were assigned thresholds of: mean daily temperature 32°F, 1.00 inch or more of snow cover and 0.50 inch of precipitation as the threshold between favorable and unfavorable days. The maximum storage capacity each winter is estimated by a daily accounting system, where one day's flow is added to storage on days classed as unfavorable, while on favorable days the accumulated storage is reduced by one-half the daily flow. This amount can be changed from station-to-station to match the expected drawdown rate. The maximum storage estimated during each winter season is printed out at the end of the season. A final summary is presented showing the estimated storage days for each of the winter seasons along with percentiles at the .05, .10, .25, and .50 levels. A detailed chronological listing of the daily input can also be furnished that gives one an opportunity to examine the accounting process from day-to-day. Cumulative degree days to base 32°F are also listed. A freezing index is computed for each season and is defined as the difference, in degree days, between the highest and lowest values on a cumulative curve. This index can be considered a measure of the intensity of the cold period as explained in an earlier publication [17]. In the event the system is to be shut down completely during the winter, the duration of the freezing period is usually a better measure of storage needs than the estimate obtained from the favorable-unfavorable day computations.

When a high percentage of the annual precipitation falls in the form of rain or drizzle and the mean daily temperature seldom falls below 32°F (0°C) during the winter months, EPA-1 may not give reasonable estimates of storage. Olympia, Washington is an example of such a station. The

problem arises partly from the fact that precipitation can occur almost every day for weeks between the months of November and April. The amounts are often less than 0.50 inch, while at the same time the mean daily temperatures are above 32°F. Although such days are defined as favorable by EPA-1, it is obvious from a review of the daily listings that land application would be undesirable during much of this time because of saturated soil and EPA-2 should be used.

The built-in flexibility of each program is considered one of the principal features since it permits each user to determine the thresholds for his particular situation. One modification to EPA-1 eliminated the snow depth and precipitation constraints entirely. This was done to use the long-term experience at an existing high-rate infiltration system to get an estimate of the temperature threshold for high-rate infiltration systems. If a waste treatment system in a cold region has been operating for many years without being seriously hampered by weather conditions, it follows that similar systems should be able to operate in a similar climate. The mean daily temperature threshold was reduced to a point where the lowest storage estimate at the control station was reduced to a minimum as a best approximation of a reasonable threshold value.

The station selected for this special processing was Lake George, New York, which has operated on a 12-month basis for 40 years despite its relatively cold climate. Spier Falls, New York, about 15 miles to the south, was selected as the weather station with the most suitable climatological record. The temperature threshold was lowered from 32° to 10° F, and each day below this threshold was considered unfavorable. Storage days were estimated using the same daily accounting system as before. These values ranged from 21 days during the most unfavorable season, to one day during the most favorable season.

With this background for the Lake George area, runs were then made using the same 10°F threshold for La Crosse, Wisconsin, and Greenville, Maine, again without regard to snow depth or precipitation. Table 1 gives the results of these runs, along with comparative values based on standard thresholds.

Another modification suggested by Parmalee [18] and Griffes [19] resulted in the development of the EPA-3 program. The proposed changes to EPA-1 included the use of the daily maximum and minimum temperatures instead of the daily mean temperature as the criteria for an unfavorable day. In addition, the daily accounting system was changed slightly and the summary table includes several additional statistics. The storage gain on UNF days is equal to the daily flow (Q). On L days, the gain is equal to the daily flow (Q) minus one-half the assigned drawdown rate, while on FAV days the decrease in storage is equal to the daily flow minus the drawdown rate (DD). The summary table shows the mean number of storage days, the standard deviation of the samples, the unbiased third moment about the mean and the coefficient of skewness. Finally, storage days are computed using the Pearson Type III method. Detailed information about the EPA-3 program can be found in Appendix A.

Program: P03B75-NCC-EPA-1 (Modified)

Spier Falls, N. Y.			Greenville, Maine			La Crosse, Wis.		
Mean Jan. Temp. 20.4 F			Mean Jan. Temp. 12.5 F			Mean Jan. Temp. 16.1 F		
(a)	YEAR	(b)	(a)	YEAR	(b)	(a)	YEAR	(b)
21.0	1969	132.5	25.0	1970	164.5	13.5	1964	123.5
14.0	1962	121.5	30.0	1958	149.5	18.5	1950	133.5
18.0	1960	107.0	29.5	1971	172.0	19.0	1958	123.0
10.0	1967	108.5	20.0	1964	152.0	20.5	1970	119.5
8.5	1970	137.0	30.5	1960	152.0	20.0	1962	98.0
3.0	1958	125.0	20.5	1962	158.0	8.0	1955	133.0
9.5	1963	116.0	30.5	1967	122.0	7.5	1949	113.5
7.0	1961	110.5	13.5	1968	176.0	12.5	1961	119.0
8.0	1964	107.5	13.5	1955	160.5	15.0	1971	120.5
3.0	1968	131.5	24.0	1961	146.5	12.5	1968	109.5
5.0	1966	104.5	10.5	1949	147.0	15.0	1969	108.5
2.5	1971	138.5	12.0	1966	153.5	13.0	1948	104.0
4.0	1955	130.0	15.5	1963	145.5	12.0	1951	119.0
4.5	1965	96.0	18.0	1969	150.0	6.0	1966	107.0
6.0	1954	92.5	18.5	1956	139.0	11.5	1956	98.0
3.0	1959	114.5	12.5	1951	156.5	8.0	1954	112.5
5.5	1956	93.5	13.0	1954	146.0	5.0	1959	115.5
3.5	1951	129.5	6.5	1965	164.5	17.0	1965	80.0
3.5	1958	104.5	8.5	1959	157.5	12.0	1972	97.0
4.5	1953	73.0	15.5	1953	136.0	3.0	1952	111.5
2.0	1950	97.5	6.0	1950	132.5	7.5	1957	95.5
1.0	1952	73.0	7.0	1952	131.5	13.0	1963	90.0
			9.0	1957	152.5	10.0	1960	70.0
						7.0	1953	84.5
						11.0	1967	76.0
Max	21	139	31		176	21		134
10%	17	135	30		169	19		127

Table 1 Estimated annual storage days based on

- (a) mean daily temperature $\leq 10^{\circ}$ F, and
- (b) standard thresholds of $\leq 32^{\circ}$ F, snow depth ≥ 1.00 inch and precipitation ≥ 0.50 inch

SECTION V

ESTIMATING STORAGE CAPACITY IN WET REGIONS

The principal climatic constraint to land application at locations along the Gulf States and the Pacific Northwest Coastal Region is prolonged wet spells, rather than cold or snow. Program EPA-2 examines daily climatological data during a 20 to 25 year period in an attempt to identify days when the soil is saturated. If land application is undesirable during periods when surface runoff could occur, the longest consecutive period defined as "wet" would be an estimation of storage needs. Palmer [2] developed a program that examines weekly (and monthly) temperature and precipitation in order to estimate the duration and magnitude of abnormal moisture deficiency. His analysis yields successive index values on weekly (or monthly) periods for State Climatic Divisions and is currently used to identify meteorological drought.

In the original program, positive index values indicate that the moisture supply from current or antecedent rainfall exceeded the amount required to sustain the evapotranspiration, runoff and moisture storage which could be considered as normal and appropriate for the climate of the area. High positive values mean that fields are too wet to work, or that rains have actually caused flooding. Rains in excess of the estimated water use produce positive values of recharge until the soils reach field capacity. Excess water then shows up as runoff. His classification system is given in Table 2.

TABLE 2
Drought Classification
by Palmer

Index	Degree
> 4.00	Extremely wet
3.00 to 3.99	Very wet
2.00 to 2.99	Moderately wet
1.00 to 1.99	Slightly wet
.50 to .99	Incipient wet spell
.49 to -.49	Near normal
-.50 to -.99	Incipient drought
-1.00 to -1.99	Mild drought
-2.00 to -2.99	Moderate drought
-3.00 to -3.99	Severe drought
< -4.00	Extreme drought

The underlying concept of Palmer's work is that the amount of precipitation required for the near-normal operation of the agricultural economy of an area during some stated period is dependent on the average climate of the area and on the prevailing meteorological conditions, both during and preceding the period in question. Although his goal was to identify droughts, he found it necessary to identify the entire range of conditions from dry to wet, as shown above. His program appears to work well in identifying droughts and thus became an obvious choice in an attempt to identify prolonged wet spells.

A soil's ability to hold water is dependent upon the thickness of its various horizons, its texture, bulk density, percentage of coarse fragments and the organic content in the profile. The available water capacity (AWC) is commonly defined as the amount of water available to plant roots from the surface to bedrock, or to the unconsolidated non-conforming material such as sand or gravel, or to an arbitrary depth in the case of deep soils [13].

The effect of changing the AWC in the EPA-2 program does not change the number of storage days significantly. This apparently is caused by several factors, perhaps the most obvious is that when wet spells occur, the rainfall is more than sufficient to saturate the soil regardless of its assigned AWC. The surface layer of the soil is assumed to be roughly equivalent to the plow layer. At field capacity it is expected to hold one inch of the available moisture. This is the layer onto which the rain falls and from which evaporation takes place. Therefore, in the moisture accounting it is assumed that evapotranspiration takes place at the potential rate from this surface layer until all the available moisture in the layer has been removed. Only then can moisture be removed from the underlying layer of soil. Likewise, it is assumed that there is no recharge to the underlying portion of the root zone until the surface layer has been brought to field capacity. The available capacity of the soil in the lower layer depends on the depth of the effective root zone and on the soil characteristics in the area under study. It is further assumed that the loss from the underlying layer depends on initial moisture content as well as on the computed potential evapotranspiration (PE) and the available water capacity (AWC) of the soil system.

The distribution of the estimated annual storage days for 25 years from EPA-2 may be a good indicator of how the program is working. One knows from experience that soils are neither always wet nor always dry.

Furthermore, the occurrence of extremely long wet periods is a rarity in most places. The summary of the annual values for 25 years should reveal an almost predictable distribution in terms of range and maximum values. To be more explicit, a large number of years with no storage days, or of estimates over 100 days due to saturated soil, would be suspect almost everywhere except deserts and swamps.

Palmer's original program dealt specifically with weekly and monthly time periods and although he considered the antecedent conditions, it was not necessary for him to be concerned with the amount of runoff. In the daily accounting, the assigned depletion rate serves to approximate the actual drying rate of the soil. It is essential to the program, but it can be changed to suit different conditions. This artificial method of gradually reducing the excess daily runoff is simply a means of accounting for the long-term effect of extremely heavy rainfall. It is a way of describing the continuing restrictive factors of daily amounts over and above that which would just cause saturation. The program defines a day as unfavorable whenever the amount of moisture in the surface soil (SS), plus that in the underlying soil (SU) and the accumulated daily runoff depleted by a constant (SRO) is equal to or greater than the assigned AWC.

About 75 stations have been processed on the original EPA-2 program that defines a day with runoff as unfavorable. Examination of the daily listings for a number of stations revealed some interesting conditions. Days following those with runoff frequently showed a moisture content in the surface layer very close to saturation. Since the surface layer had not dried out enough to accept the intended amount of application, these days should also be classed as unfavorable and the string of storage days continued. The program was modified to check the amount of moisture in the surface (SS) layer as well as the runoff and to class either condition as unfavorable. The amount of moisture in the surface layer at saturation is always 1.00 inch, with the remainder of the AWC assigned to the underlying layer (SU). Thus, if one selects 0.10 inch as the daily application rate it may be necessary to consider days with SS equal to or greater than 0.90 inch as unfavorable along with those when saturation is indicated. When this feature is used, the program indicator is followed by the percent of SS being considered. For example, in the case stated above, the indicator would be EPA-2(10%); if the application rate was 0.20 inch, the indicator would be EPA-2(20%), etc. This simply says the amount of moisture needed before the surface layer is saturated is the difference between the amount of moisture in that layer and 1.00 inch. This feature may also be useful to planners in estimating irrigation requirements in some areas. Additional changes would have to be made to include a check on the amount of moisture in both SS and SU. The general concept would be to establish minimum moisture needs and then analyze the daily data in terms of the frequency, duration and even total moisture deficit by months, or other time periods.

Examination of the daily listings from EPA-2 shows that most of the wet periods occur during the winter months when evapotranspiration is lowest. The heavy rains of summer do not often result in significant wet spells for a number of reasons. The soil is more likely to be at less than capacity and therefore, in need of recharge. Also, evapotranspiration rates are highest during the growing season. Detailed information about the EPA-2 program is given in Appendix A.

SECTION VI

DISCUSSION

Daily weather reports from the principal observing stations usually include measurements of a number of elements, such as temperature, precipitation, snowfall, snow depth, winds, relative humidity, sunshine, sky cover, etc. These observations have been reported regularly from a network of about 300 stations in the United States for many years, but have been placed on magnetic tape only since about 1948. This network is staffed by meteorologists and most of the stations are located at airports.

Another important source of weather reports is the cooperative network of approximately 10,000 to 12,000 stations. These stations are operated by dedicated volunteers from all walks of life who are making a significant contribution to climatology. Daily reports from this network generally consist of temperature, precipitation, snowfall, snow depth and remarks about unusual weather events. Some networks report only precipitation and river stages, while others include soil temperature and soil moisture measurements. State universities and other interested organizations have made a special effort to place these climatological observations on magnetic tape prior to 1948. Several hundred stations now have digitized record as far back as 1895, or earlier.

In general, observing networks have been established primarily to provide specific weather information to a particular segment of the economy. Some are multi-purpose, of course, and most overlap to some degree. Aviation, hydrology and agriculture are a few examples that need unique and different measurements of the environment. Weather forecasting probably has the broadest base of all in its use of weather observations on a current, or real-time basis. The operational use of weather data is only part of the total picture. Most weather records forwarded to the NCC are edited, sorted and placed in magnetic tape files for future processing. While statistical analysis of climatological data can be very useful, it also has limitations.

One of the first steps in applying climatological data to a specific problem is to insure the presence of an adequate base in digital form (magnetic tape). Consideration should be given to the quality, completeness and length of record, as well as having a large number of stations well distributed throughout the country. The tape decks meeting the above criteria at the NCC are TD-30 and TD-486.

Inventories should be reviewed for completeness before the data can be processed by the programs discussed in this report. If the requested record is inadequate, a substitute station must be used, since a significant number of missing elements or days can bias the results. This means that climatological data from stations 50 to 75 miles from the proposed site may sometimes be used. While each program furnishes selected information about weather conditions at a station during the past quarter of a century, the lack of refinement is obvious. Thresholds to be assigned should be determined by specialists on the site since numerous factors complicate the relationship between rainfall, temperature and wet periods.

Although there is reason to believe that the output from these programs can provide realistic estimates of storage requirements, the limitations are so great in some areas that any measure of confidence may be misleading. At best, these programs offer a simple approximation of storage based on the examination of a few elements. Palmer, and others, developed the basic computer program that provides a realistic picture of moisture excesses and deficiencies many years ago. As more complete and longer records become available, more refined methods of estimating storage will be developed. Future studies will undoubtedly include such elements as solar radiation, wind, moisture and temperature measurements at selected levels above and below the ground, evaporation, precipitation, and others. The present practice at some observing sites of recording certain weather elements only during the growing season should be expanded to include all months. In any case, it is hoped that some of the material presented in this report will stimulate others to examine the data base and respond with improved methods and techniques for estimating storage days.

Finally, daily observations from the cooperative stations reflect weather conditions that existed during the previous 24-hour period. These periods do not coincide with calendar days, since most cooperative observers take their observations in the morning (7 a.m.), or in the evening (5 p.m.). It is entirely possible for one or more of the reported values to have occurred on the previous day. Since there is no real solution to this dilemma, except by having all stations report on a midnight-to-midnight basis, it is the practice in most climatological data processing programs to ignore differences in the hours of observation. For example, it is impossible to tell from the digital records, or indeed, even from some of the original records from the 7 a.m. and 5 p.m. reporting stations, on which date the reported rain actually fell.

SECTION VII

REFERENCES

1. Hill, Jerry D., "The Use of a 2-Layer Model to Estimate Soil Moisture Conditions in Kentucky," Monthly Weather Review, Vol. 102, No. 10, October 1974, 5 p.
2. Palmer, Wayne C., "Meteorological Drought," Research Paper No. 45, U. S. Department of Commerce, Weather Bureau, Washington, D. C., February 1965, 58 p.
3. "Report of Conference on Soil Trafficability Prediction," U. S. Army Engineer Waterways Experiment Station, Corps of Engineers, Vicksburg, Mississippi, November 1966, 125 p.
4. Smith, M. H. and M. P. Meyer, "Automation of a Model for Predicting Soil Moisture and Soil Strength" (SMSP Model), Miscellaneous Paper M-73-1, U. S. Army Engineer Waterways Experiment Station, Mobility and Environmental Systems Laboratory, Vicksburg, Mississippi, January 1973, 120 p.
5. Thornthwaite, C. W. and J. R. Mather, "The Water Balance," Publications in Climatology, Vol. VIII, Number 1, Drexel Institute of Technology, Laboratory of Climatology, Centerton, N. J., 1955, 104 p.
6. Mather, John R., "The Climatic Water Balance," Publications in Climatology, Volume XIV, Number 3, C. W. Thornthwaite Associates, Laboratory of Climatology, Centerton, N. J., 1961, pp. 249-264.
7. Barger, G. L., Robert Shaw, and R. F. Dale, "Chances of Receiving Selected Amounts of Precipitation in the North Central Region of the U. S.," Agricultural and Home Economics Experiment Station, Iowa State University of Science and Technology, Ames, Iowa, July 1959, 277 p.
8. Barger, G. L., Robert Shaw, and R. F. Dale, "The Gamma Distribution from 2- and 3-Week Precipitation Totals in the North Central Region of the U. S.," Agricultural and Home Economics Experiment Station, Iowa State University of Science and Technology, Ames, Iowa, Dec. 1959, 183 p.
9. Barger, Gerald L., "Weather Planning for Direct Seeding of Southeastern Pines," reprinted from "Direct Seeding in the South," 1959, 12 p.

References - cont'd

10. Pengra, Ray F., "Seasonal Variations of Soil Moisture in South Dakota," Agricultural Economics Pamphlet No. 99, Agricultural Experiment Station, S. D. State College, Brookings, S. D., February 1959.
11. Pierce, L. T., "A Practical Method of Determining Evapotranspiration from Temperature and Rainfall," paper presented at the American Society of Agricultural Engineers, Chicago, Ill., December 1956, 6 p.
12. van Bavel, C. H. M., "Agricultural Drought in North Carolina," Technical Bulletin No. 122, North Carolina Agricultural Experiment Station, North Carolina State College, Raleigh, N. C., June 1956, 35 p.
13. "Guide for Sediment Control on Construction Sites," U. S. Department of Agriculture, Soil Conservation Service, Raleigh, N. C., March 1973, 122 p.
14. "Precipitation-Frequency Atlas of the Western United States," NOAA-Atlas-2, U. S. Department of Commerce, National Oceanic and Atmospheric Administration, National Weather Service, Hydrology, Silver Spring, Maryland. Volumes I-XI, 1973, 50 p.
15. Technical Paper #40, Hydrology, National Weather Service, National Oceanic and Atmospheric Administration, Silver Spring, Maryland, May 1961, 115 p.
16. Technical Paper #49, Hydrology, National Weather Service, National Oceanic and Atmospheric Administration, Silver Spring, Maryland, May 1964, 29 p.
17. "Use of Climatic Data in Design of Soils Treatment Systems," U. S. Environmental Protection Agency Office of Research and Development, EPA-660/2-75-018, Corvallis, Oregon, June 1975, 67 p.
18. Parmalee, Donald M., Consultant, Alloway, New Jersey, Camp Edge Road, personal correspondence, 1975.
19. Griffes, Douglas A., Metcalf & Eddy Engineers, Palo Alto, California, personal correspondence, 1976
20. Thom, H. C. S., "New Distributions of Extreme Winds in the United States." In: "Journal of the Structural Division, Proceedings of the American Society of Civil Engineers," Vol. 94, No. ST 7, July 1968, 12 p.
21. "Glossary of Meteorology," edited by Ralph E. Huschke, American Meteorological Society, Boston, Massachusetts, 1959, 638 p.
22. Holzworth, George C., "A Climatological Analysis of Pasquill Stability Categories based on 'STAR' summaries," Environmental Protection Agency, Environmental Sciences Research Laboratory, Research Triangle Park, North Carolina, April 1976, 51 p.

References (cont'd)

23. "Evaluation of Land Application Systems," U. S. Environmental Protection Agency, Technical Bulletin, EPA-430/9-75-001, Office of Water Program Operations, Washington, D. C., March 1975, 182 p.
24. "Factors Involved in Land Application of Agricultural and Municipal Wastes," U. S. Department of Agriculture, Agricultural Research Service, Beltsville, Maryland, July 1974, 200 p.
25. Pound, Charles E. and Ronald W. Crites, Metcalf and Eddy Engineers, "Design Seminar for Land Treatment of Municipal Wastewater Effluents," Design Factors, Part I, Palo Alto, California, April 1975.
26. Sorber, C. A., "Protection of Public Health," Proceedings of the Conference on Land Disposal of Municipal Effluents and Sludges," Rutgers University, New Brunswick, N. J., March 1973.
27. Cry, George W., "Effects of Tropical Cyclone Rainfall on the Distribution of Precipitation Over the Eastern and Southern United States," Environmental Science Services Administration, U. S. Department of Commerce, Washington, D. C., June 1967, 195 p.
28. "Environmental Guide for the U. S. Gulf Coast," National Oceanic and Atmospheric Administration, Environmental Data Service, National Climatic Center, Asheville, North Carolina, November 1972, 177 p.
29. "Environmental Guide for Seven U. S. Ports and Harbor Approaches," National Oceanic and Atmospheric Administration, Environmental Data Service, National Climatic Center, Asheville, North Carolina, February 1972, 166 p.
30. W. B. Langbein, "Water Yield and Reservoir Storage in the United States," Geological Survey Circular 409, U. S. Department of the Interior, Geological Survey, 1959.
31. A. F. Meyer, "Evaporation from Lakes and Reservoirs," Minnesota Resources Commission, St. Paul, Minn., 1942.
32. R. E. Horton, "Evaporation Maps of the United States," Transactions American Geophysical Union, Vol. 24, Part 2, April 1943, pp. 750-751.
33. "Water-Loss Investigations: Vol. 1 -- Lake Hefner Studies," Geological Survey Professional Paper No. 269, U. S. Geological Survey, 1954.
34. "Water-Loss Investigations: Lake Mead Studies," Geological Survey Professional Paper No. 298, U. S. Geological Survey, 1958.
35. M. A. Kohler, T. J. Nordenson, and W. E. Fox, "Evaporation from Pans and Lakes," Research Paper No. 38, U. S. Weather Bureau, 1955.

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APPENDIX A

THE COMPUTER PROGRAMS

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STATION	LENGTH OF FREEZE PERIOD (10 °N)	ESTIMATED STORAGE DAYS (10 °N)	FREEZE INDEX (10 °N) (BASE 32 °F)	LENGTH OF MAXIMUM FREEZE PERIOD (DAYS)	ESTIMATED MAXIMUM STORAGE DAYS	NORMAL JANUARY TEMPERATURE	GROWING SEASON (DAYS)	YEARS
BIRMINGHAM, AL	008	012	0061	013	015	44.2	241	24
MADISON, AL	018	019	0075	020	021	41.2	215	22
MOBILE, AL	004	005	0019	004	006	51.2	298	20
MUSCLE SHOALS, AL	014	018	0089	016	021	41.3	230	25
ONEONTA, AL	012	017	0085	014	020	41.9	219	24
ST. BERNARD, AL	016	018	0100	020	021	40.9	204	20
SCOTTSBORO, AL	012	016	0095	017	020	41.1	210	25
SELMA, AL	004	005	0037	004	006	49.1	262	23
THOMASVILLE, AL	006	008	0041	007	009	47.4	242	20
ASH FORK, AZ	025	024	0115	045	040	36.8	155	22
GANADO, AZ	110	074	0633	114	078	27.5	129	21
CORNING, AR	023	022	0150	024	022	37.7	207	20
DUMAS, AR	011	013	0075	014	021	43.7	223	22
FAYETTEVILLE, AR	029	018	0145	033	031	37.1	181	27
GILBERT, AR	021	020	0154	025	023	37.3	179	20
LITTLE ROCK, AR	018	016	0091	020	019	39.5	238	25
NASHVILLE EXP STN, AR	014	012	0087	017	015	41.9	219	23
NEWPORT, AR	020	016	0094	023	022	40.2	215	21
WALDRON, AR	016	012	0080	017	013	40.8	199	25
CEDARVILLE, CA	066	071	0437	075	072	29.6	131	20
LOS ANGELES, CA	001	004	0001	001	004	54.5	350	25
SALINAS, CA	001	004	0001	001	004	50.0	262	20
SAN FRANCISCO, CA	001	005	0001	001	007	48.3	350	25
SANTA CRUZ, CA	001	006	0001	001	007	48.8	279	24
SUSANVILLE, CA	060	059	0418	068	061	29.9	121	22
TAHOE CITY, CA	123	164	0758	130	169	28.2	075	22
BOULDER, CO	052	049	0346	056	058	33.0	148	24
DENVER, CO	082	056	0563	100	065	29.9	150	24
DURANGO, CO	110	099	0642	112	116	25.9	106	22
FORT COLLINS, CO	105	067	0587	122	071	26.8	140	23
LAMAR, CO	065	046	0531	069	053	29.3	160	22
STRATTON, CO	088	066	0571	094	102	29.7	153	23
TRINIDAD, CO	065	047	0450	093	065	31.0	156	22
BRIDGEPORT, CT	083	064	0410	084	068	30.2	135	23
WILMINGTON, DE	062	053	0312	081	061	32.0	191	25
APALACHICOLA, FL	001	003	0006	002	003	53.7	322	24
AVON PARK, FL	001	002	0001	001	005	62.9	344	27
DAYTONA BEACH, FL	001	003	0001	001	005	58.4	326	17
FT. MYERS, FL	001	003	0001	001	005	63.5	365	24
HOMESTEAD, FL	001	003	0001	001	006	65.3	344	24
JACKSONVILLE, FL	002	003	0006	003	004	54.6	313	19
TAMPA, FL	001	004	0001	001	005	60.4	349	21
WEST PALM BEACH, FL	001	004	0001	001	004	65.5	365	21

Table 3 Selected information for stations, EPA-1 program

STATION	LENGTH OF FREEZE PERIOD (10 °F)	ESTIMATED STORAGE DAYS (10 °F)	FREEZE INDEX (10 °F) (BASE 32 °F)	LENGTH OF MAXIMUM FREEZE PERIOD (DAYS)	ESTIMATED MAXIMUM STORAGE DAYS	NORMAL JANUARY TEMPERATURE	GROWING SEASON (DAYS)	YEARS
ATHENS, GA	008	010	0044	010	016	44.5	221	24
AUGUSTA, GA	004	005	0026	005	007	45.8	219	23
ATLANTA, GA	012	011	0055	014	016	42.4	236	24
BLAIRSVILLE EXP STA, GA	035	031	0154	053	048	37.8	172	25
MACON, GA	004	005	0030	004	007	47.8	240	23
BOISE, ID	085	077	0476	094	087	29.0	159	24
CAMBRIDGE, ID	115	101	1256	122	120	22.5	117	24
LEWISTON, ID	050	048	0505	063	059	31.2	179	25
POCATELLO, ID	116	109	1252	125	125	23.2	142	25
CAIRO, IL	022	028	0179	035	034	36.3	230	25
CHICAGO, IL/MIDWAY	093	081	0954	129	086	24.3	192	25
HOOPESTON, IL	095	072	0746	119	076	26.2	170	25
MOLINE, IL	110	092	1106	135	095	21.5	174	25
MT. VERNON, IL	076	042	0342	080	046	32.1	191	24
PANA, IL	076	061	0519	086	065	28.9	186	25
PEORIA, IL	095	083	0906	129	088	23.8	181	25
BERNE, IN	089	074	0661	101	086	27.1	160	25
COLUMBUS, IN	077	061	0472	087	062	30.1	167	25
CRAWFORDSVILLE, IN	090	073	0714	101	086	27.2	163	25
EVANSVILLE, IN	060	045	0343	084	049	32.6	216	25
SOUTH BEND, IN	104	101	0926	132	109	24.0	165	25
BELLE PLAINE, IA	128	113	1387	135	126	19.8	155	25
DES MOINES, IA	128	106	1416	136	111	19.4	175	25
HAMPTON, IA	140	126	1788	146	136	16.3	144	23
KEOSAUQUA, IA	091	084	0875	119	090	24.4	168	27
LOGAN, IA	114	105	1152	128	107	20.6	162	25
SHENANDOAH, IA	101	077	0822	119	095	23.8	167	25
DODGE CITY, KS	066	048	0381	094	053	30.8	184	23
GOODLAND, KS	093	066	0614	121	073	27.6	157	23
HAYS, KS	090	064	0593	129	065	27.8	167	23
HEALY, KS	073	062	0463	094	067	29.9	164	23
HERINGTON, KS	084	052	0445	092	064	29.1	185	23
INDEPENDENCE, KS	034	026	0224	041	032	33.9	196	23
JUNCTION CITY, KS	059	049	0396	069	058	28.7	175	23
BOWLING GREEN, KY	032	039	0217	036	040	35.6	204	25
LEXINGTON, KY	073	048	0310	084	052	32.9	198	25
PADUCAH, KY	041	037	0228	047	038	36.0	209	25
ARCADIA, LA	007	012	0060	009	012	45.6	246	22
LAFAYETTE, LA	003	004	0015	004	005	51.9	275	25
LAKE PROVIDENCE, LA	007	012	0061	011	016	46.0	252	25
LEFVSVILLE, LA	004	005	0036	005	006	49.7	243	21
MONROE, LA	006	009	0051	006	010	46.7	253	25
SHREVEPORT, LA	005	006	0047	006	009	47.2	272	25
WINNFELD, LA	005	006	0043	005	008	48.4	240	21

Table 3 Selected information for stations, EPA-1 program

STATION	LENGTH OF FREEZE PERIOD (10 °F)	ESTIMATED STORAGE DAYS (10 °F)	FREEZE INDEX (10 °F) (BASE 32 °F)	LENGTH OF MAXIMUM FREEZE PERIOD (DAYS)	ESTIMATED MAXIMUM STORAGE DAYS	NORMAL JANUARY TEMPERATURE	GROWING SEASON (DAYS)	YEARS
BAR HARBOR, ME	111	128	0976	120	140	23.7	156	23
EASTPORT, ME	124	122	1012	127	130	22.6	174	23
GREENVILLE, ME	158	169	2268	159	172	12.5	110	23
BALTIMORE, MD	028	053	0183	033	055	36.1	200	22
ADAMS, MA	126	117	1266	132	123	21.0	127	25
BOSTON, MA	084	080	0418	089	081	29.2	217	25
HAVERHILL, MA	094	102	0640	112	104	26.8	181	25
WORCESTER, MA	122	118	0953	133	126	23.6	148	25
MUSKEGON, MI	124	116	1040	127	119	24.0	161	23
INTERNATIONAL FALLS, MN	161	168	3506	164	172	01.9	095	23
MINNEAPOLIS, MN	141	143	2174	146	143	12.2	166	23
PARK RAPIDS, MN	159	155	3186	164	159	05.0	122	24
ABERDEEN, MS	008	011	0051	013	013	44.7	228	24
CLARKSDALE, MS	017	016	0083	020	021	43.1	236	25
COLUMBIA, MS	003	006	0020	004	009	50.4	239	24
MERIDIAN, MS	006	008	0033	011	015	46.9	246	24
PONTOTOC, MS	010	014	0077	013	019	43.2	223	24
STONEVILLE EXP STA, MS	011	013	0077	012	017	44.2	229	23
ST. LOUIS, MO	075	044	0367	085	051	31.3	206	25
SALISBURY, MO	082	054	0470	090	071	27.8	186	25
SPRINGFIELD, MO	040	039	0274	047	043	32.9	201	25
TARKIO, MO	098	084	0869	119	090	24.0	170	22
WARSAW, MO	043	037	0296	050	038	32.5	185	23
WEST PLAINS, MO	038	033	0232	040	035	33.8	178	25
BILLINGS, MT	128	100	1342	139	102	21.9	132	25
BOZEMAN, MT	134	144	1348	137	152	20.8	107	23
DILLON, MT	138	128	1647	139	132	20.2	099	25
GREAT FALLS, MT	128	091	1557	132	102	20.5	135	25
MILES CITY, MT	134	143	2356	138	140	15.4	150	25
MISSOULA, MT	133	121	1309	137	128	20.8	095	25
GRAND ISLAND, NE	121	098	1173	132	103	22.3	151	25
IMPERIAL, NE	093	082	0765	121	092	26.9	150	25
SCOTTSDUFF, NE	117	075	0804	134	081	24.9	135	25
VALENTINE, NE	128	104	1401	136	119	20.4	146	25
ADAVEN, NV	085	086	0425	096	102	30.6	119	24
ELKO, NV	124	117	1230	125	124	23.2	089	25
ELY, NV	133	120	1362	134	137	23.6	126	25
LOVELOCK, NV	083	061	0459	087	080	28.9	135	25
RENO, NV	058	050	0374	064	067	31.9	141	25

Table 3 Selected information for stations, EPA-1 program

STATION	LENGTH OF FREEZE PERIOD (10 %)	ESTIMATED STORAGE DAYS (10 %)	FREEZE INDEX (10 %) (BASE 32 °F)	LENGTH OF MAXIMUM FREEZE PERIOD (DAYS)	ESTIMATED MAXIMUM STORAGE DAYS	NORMAL JANUARY TEMPERATURE	GROWING SEASON (DAYS)	YEARS
LEBANON, NM	136	135	1569	137	147	18.1	120	25
ATLANTIC CITY, NJ	040	032	0138	045	036	32.7	225	25
NEWARK, NJ	070	054	0302	082	059	31.4	219	25
TRENTON, NJ	064	053	0280	083	056	32.1	218	25
ALBUQUERQUE, NM	034	024	0159	057	026	35.2	196	24
ARTESIA, NM	013	013	0160	013	013	40.8	220	21
CIMARRON, NM	074	034	0296	099	074	32.2	150	25
CLAYTON, NM	049	035	0235	056	042	33.1	166	25
CLOVIS, NM	018	015	0149	018	020	37.2	198	22
SANTA FE, NM	095	065	0493	095	065	29.8	165	17
BUFFALO, NY	119	103	0948	126	108	23.7	179	25
ELMIRA, NY	120	104	1021	125	113	25.0	156	25
POUGHKEEPSIE, NY	089	086	0760	108	092	26.5	177	25
ROCHESTER, NY	124	115	0970	125	121	24.0	176	23
SPIER FALLS, NY	125	135	1405	138	139	20.4	150	23
SYRACUSE, NY	117	115	0975	125	118	23.6	168	25
WATERTOWN, NY	127	126	1467	132	128	18.8	151	25
CANTON, NC	023	035	0171	052	041	38.0	195	25
CHARLOTTE, NC	010	011	0052	010	014	42.1	239	25
ELIZABETH CITY, NC	010	013	0036	011	016	42.3	226	25
FAYETTEVILLE, NC	008	010	0045	013	012	43.0	222	25
GREENSBORO, NC	016	024	0086	023	030	38.7	211	25
HICKORY, NC	013	020	0070	020	025	39.1	210	24
LAURINBURG, NC	006	008	0028	009	012	43.9	212	25
MAYSVILLE, NC	009	011	0040	013	012	45.0	241	23
RALFIGH, NC	013	017	0041	021	021	40.5	237	25
SALISBURY, NC	010	014	0061	016	015	40.9	205	25
WELDON, NC	015	017	0082	021	029	40.5	193	23
WILMINGTON, NC	004	007	0023	006	007	46.4	262	25
WILSON, NC	008	011	0044	011	015	42.5	222	24
BISMARCK, ND	146	140	3103	148	144	08.2	136	24
DEVILS LAKE, ND	158	156	3533	165	168	04.2	127	24
WILLISTON, ND	144	141	2975	147	146	08.3	132	24
AKRON CANTON, OH	103	087	0761	109	092	26.3	173	25
COLUMBUS, OH	084	071	0578	087	076	28.4	196	25
DAYTON, OH	084	069	0599	092	071	28.1	165	25
FINDLAY, OH	106	088	0772	130	095	25.8	160	25
ADA, OK	017	013	0085	020	014	40.9	220	22
BARTLESVILLE, OK	022	020	0170	025	020	35.4	210	23
HOBART, OK	020	018	0169	026	020	37.3	210	23
MADILL, OK	013	010	0069	018	012	42.1	227	23
OKLAHOMA CITY, OK	022	018	0166	026	020	36.8	223	22
PAULS VALLEY, OK	013	014	0091	016	016	39.7	207	23
POTEAU, OK	016	012	0082	018	014	41.1	212	23

Table 3 Selected information for stations, EPA-1 program

STATION	LENGTH OF FREEZE PERIOD (10 %)	ESTIMATED STORAGE DAYS (10 %)	FREEZE INDEX (10 %) (BASE 32 ° F)	LENGTH OF MAXIMUM FREEZE PERIOD (DAYS)	ESTIMATED MAXIMUM STORAGE DAYS	NORMAL JANUARY TEMPERATURE	GROWING SEASON (DAYS)	YEARS
BURNS, OR	108	102	0774	122	119	25.2	111	25
EUGENE, OR	010	026	0119	027	032	39.4	199	25
KLAMATH FALLS, OR	087	089	0400	103	091	29.7	126	25
MEDFORD, OR	018	020	0085	025	022	36.6	184	25
PENDLETON, OR	037	042	0526	062	052	32.0	196	25
PORTLAND, OR	014	027	0094	023	037	38.1	211	25
REDMOND, OR	044	049	0379	075	071	30.2	075	23
ROSEBURG, OR	006	010	0056	008	015	40.9	219	28
SALEM, OR	012	023	0101	028	029	38.8	192	25
ERIE, PA	113	098	0741	114	109	25.1	200	23
PHILADELPHIA, PA	068	057	0322	083	064	32.3	190	25
PITTSBURGH, PA	069	049	0421	085	053	28.1	187	25
STATE COLLEGE, PA	104	094	0709	113	106	27.0	166	25
WILLIAMSPORT, PA	093	088	0726	098	095	27.2	164	25
PROVIDENCE, RI	089	076	0526	090	080	28.4	197	24
CHARLESTON, SC	003	004	0018	004	006	48.6	294	24
COLUMBIA, SC	005	006	0025	005	007	45.4	252	25
CONWAY, SC	004	006	0024	005	008	46.5	240	26
FLORENCE, SC	005	008	0024	006	009	45.6	241	25
RAINBOW LAKE, SC	007	012	0041	009	012	42.1	210	25
SUMMERVILLE, SC	004	005	0021	004	006	47.4	252	25
ABERDEEN, SD	145	138	2690	148	142	09.5	137	25
BROOKINGS, SD	144	131	2365	147	136	12.0	137	24
PIERRE, SD	136	126	2205	142	136	15.6	155	25
RAPID CITY, SD	128	099	1291	136	100	21.9	150	25
CHATTANOOGA, TN	012	020	0097	020	022	40.2	229	25
CROSSVILLE, TN	054	052	0322	085	055	34.5	176	20
KINGSPORT, TN	022	024	0146	022	028	36.4	190	27
KNOXVILLE, TN	021	022	0125	035	031	40.6	220	25
MEMPHIS, TN	019	017	0108	022	025	40.5	237	25
NASHVILLE, TN	022	028	0150	032	031	38.3	224	25
AMARILLO, TX	021	023	0205	031	027	36.0	191	25
CORPUS CHRISTI, TX	001	003	0003	003	005	56.3	306	21
DALHART, TX	038	027	0195	051	032	33.8	185	24
DALLAS, TX	005	008	0052	007	010	45.4	239	25
EL PASO, TX	005	005	0048	006	006	43.6	243	24
LUBBOCK, TX	016	014	0118	018	020	39.1	204	24
LUFKIN, TX	004	005	0034	006	006	48.8	231	24
MIDLAND, TX	006	007	0058	007	010	43.6	232	24
WICHITA FALLS, TX	016	015	0090	018	017	41.5	216	24
BLANDING, UT	098	091	0623	109	110	27.7	148	25
HANKSVILLE, UT	082	073	0934	090	089	26.1	156	24
LOGAN, UT	130	109	0931	131	113	24.0	165	21
MILFORD, UT	112	090	1007	129	101	25.7	128	25
NEPHI, UT	092	075	0675	109	089	26.0	137	23
SALT LAKE CITY, UT	098	089	0765	107	115	28.0	202	25

Table 3 Selected information for stations, EPA-1 program

STATION	LENGTH OF FREEZE PERIOD (HOURS)	ESTIMATED STORAGE DAYS (HOURS)	FREEZE INDEX (HOURS BASE 32°F)	LENGTH OF MAXIMUM FREEZE PERIOD (DAYS)	ESTIMATED MAXIMUM STORAGE DAYS	NORMAL JANUARY TEMPERATURE	GROWING SEASON (DAYS)	YEAR
BURLINGTON, VT	138	134	1800	143	136	16.8	148	25
BLACKSTONE, VA	016	025	0100	026	031	38.3	181	24
HOT SPRINGS, VA	080	066	0338	101	067	31.6	135	22
NORFOLK, VA	013	015	0059	017	022	40.5	219	25
WASHINGTON, DC/NATIONAL	039	034	0122	062	047	35.6	200	25
LONGVIEW, WA	021	029	0104	028	049	38.2	182	24
OLYMPIA, WA	034	035	0227	034	045	37.2	144	23
SEATTLE, WA	022	033	0081	034	036	38.2	233	25
SPOKANE, WA	105	100	0953	124	106	25.4	169	25
SUNNYSIDE, WA	058	050	0536	102	059	30.5	158	25
VANCOUVER, WA	028	028	0192	033	034	38.4	233	23
WALLA WALLA, WA	036	042	0476	054	051	33.4	202	25
WENATCHEE, WA	093	087	0849	110	122	26.6	188	22
BLUESTONE DAM, WV	065	052	0322	084	058	31.1	150	25
CHARLESTON, WV	065	044	0272	084	049	34.5	193	25
MORGANTOWN, WV	072	060	0486	085	070	31.5	165	25
ASHLAND, WI	147	148	2353	149	149	12.1	109	22
EAU CLAIRE, WI	144	141	2339	148	147	11.7	151	24
GREEN BAY, WI	140	135	1932	148	139	15.4	161	25
LACROSSE, WI	139	127	1925	146	134	16.1	161	25
MADISON, WI	134	119	1700	146	125	16.8	177	25
RHINELANDER, WI	146	149	2344	147	156	12.3	085	21
WEYERHAEUSER, WI	145	145	2289	150	148	11.3	125	21
AFTON, WY	149	144	2163	159	156	14.3	018	25
CASPER, WY	136	095	1140	138	101	23.2	130	25
GILLETTE, WY	134	108	1229	125	113	21.7	129	22
ROCK SPRINGS, WY	145	136	1718	151	142	19.2	060	25
WHEATLAND, WY	099	058	0536	127	066	28.9	102	25

Table 3 Selected information for stations, EPA-1 program

Station	Normal January Temp. (°F)	Normal Annual Precip. (in.)	EPA-1	EPA-2	General Period	Station	Normal January Temp. (°F)	Normal Annual Precip. (in.)	EPA-1	EPA-2	General Period
<u>Alabama</u>						<u>North Carolina</u>					
Mobile	51	67	6	15	1949-73	Charlotte	42	42	14	12	1949-73
Selma	49	52	6	20	1949-73	Raleigh	41	43	21	14	1949-73
Thomaston	45	56	9	25	1953-74	Weldon	41	43	29	11	1926-50
						Wilmington	46	54	7	11	1949-73
<u>Arkansas</u>						<u>Oregon</u>					
Ponca	44	50	21	19	1951-71	Eugene	39	43	32	35	1948-73
Little Rock	40	49	19	12	1949-72	Medford	37	21	22	21	1948-72
<u>California</u>						Roseburg	41	34	15	22	1935-64
Los Angeles	55	12	4	5	1952-69	Salem	39	41	29	36	1948-73
San Francisco	48	20	7	13	1949-72	<u>South Carolina</u>					
<u>Florida</u>						Charleston	49	52	6	24	1948-73
Avon Park	63	55	5	13	1945-72	Columbia	45	46	7	15	1949-73
DeVona Beach	58	50	5	8	1953-73	Conway	47	52	8	9	1945-73
Tampa	60	49	5	16	1953-73	<u>Tennessee</u>					
<u>Georgia</u>						Crossville	35	57	55	24	1953-73
Augusta	46	43	7	10	1949-72	<u>Texas</u>					
Macon	48	44	7	12	1949-72	Amarillo	36	20	27	11	1949-71
<u>Louisiana</u>						Corpus Christi	56	29	5	13	1951-72
Lafayette	52	57	5	12	1948-73	Dallas	45	36	10	15	1948-72
Lake Providence	46	53	16	19	1951-72	El Paso	44	8	6	0	1948-72
Leesville	50	54	6	35	1950-73	Wichita Falls	42	27	17	8	1950-72
Monroe	47	50	10	12	1949-72	<u>Washington</u>					
Shreveport	47	45	9	11	1949-72	Longview	38	46	49	60	1948-73
Winnfield	48	55	8	16	1950-73	Olympia	37	51	45	65*	1948-73
<u>Mississippi</u>						Vancouver	38	40	34	31	1924-50
Aberdeen	45	53	13	24	1951-72	Walla Walla	33	16	51	14	1950-73
Clarksdale	43	49	21	18	1949-72						
Columbia	50	61	9	33	1947-73						
Meridian	47	52	15	14	1948-73						
Pontotoc	43	55	19	20	1949-71						
Stonerville	44	50	17	17	1951-72						

* This station shows 145 storage days when processed under EPA-2 (10%)

Fig. 2 Comparison between maximum annual storage days estimated from EPA-1 and EPA-2 programs

LIST OF SYMBOLS

STA: Station
 YR: Year (20 to 30 years of record)
 MO: Month 01 = January, 02 = February, etc.
 DA: 01 - 31
 MN: Daily minimum temperature ($^{\circ}\text{F}$)
 MX: Daily maximum temperature ($^{\circ}\text{F}$)
 T: Daily mean temperature ($^{\circ}\text{F}$)
 P: Daily precipitation (inches), Trace = 0.00
 SP: Available moisture in the soil at the start of a day. Saturation is assumed when $\text{SP} = \text{AWC}$ (available water capacity)
 SS: Amount of available moisture in the surface soil at the end of a day.
 SU: Amount of available moisture in the underlying soil at the end of a day.
 PE: Daily potential evapotranspiration (Thornthwaite)
 PL: Daily potential moisture loss
 PR: Potential recharge; at the start of a day this is the number of inches required to bring the soil to field capacity
 R: Daily recharge; net gain in the surface and underlying soil
 L: Daily moisture loss from the surface and underlying soil
 ET: Daily evapotranspiration
 DR: Depletion rate
 RO: Daily runoff
 ARO: Accumulated runoff. This is the sum of the previous days SRO and the current day's runoff;
 $\text{ARO} = \text{SRO}' + \text{RO}$
 SRO: Accumulated daily runoff minus the depletion rate; $\text{SRO} = \text{ARO} - \text{DR}$
 AWC: Available water capacity of the soil. At saturation, $\text{AWC} = \text{SS} + \text{SU}$
 UNF: "X" denotes an unfavorable day for land application because of possible surface runoff

(If $\text{SRO} + \text{SS} + \text{SU}$ is equal to or greater than the available water capacity, the day is unfavorable)

Note: Symbols with a prime (') indicate conditions at the start of a day. Subscripts s and u indicate "surface" and "underlying", respectively.

Constants which must be supplied for the station being analyzed are:

- I, the heat index
- b, a coefficient which depends on the heat index
- g, the tangent of the station's latitude
- W , the available water capacity of the soil minus 1.0 inch in inches
- ϕ , Daily solar declination, in radians

To start the analysis two values must be assigned: SS' , in inches (to hundredths) of soil moisture available in the surface soil at the start, and SU' , in inches (to hundredths) of soil moisture available in the underlying soil at the start.

Fig. 3 Explanation of symbols used in the listings from EPA-2

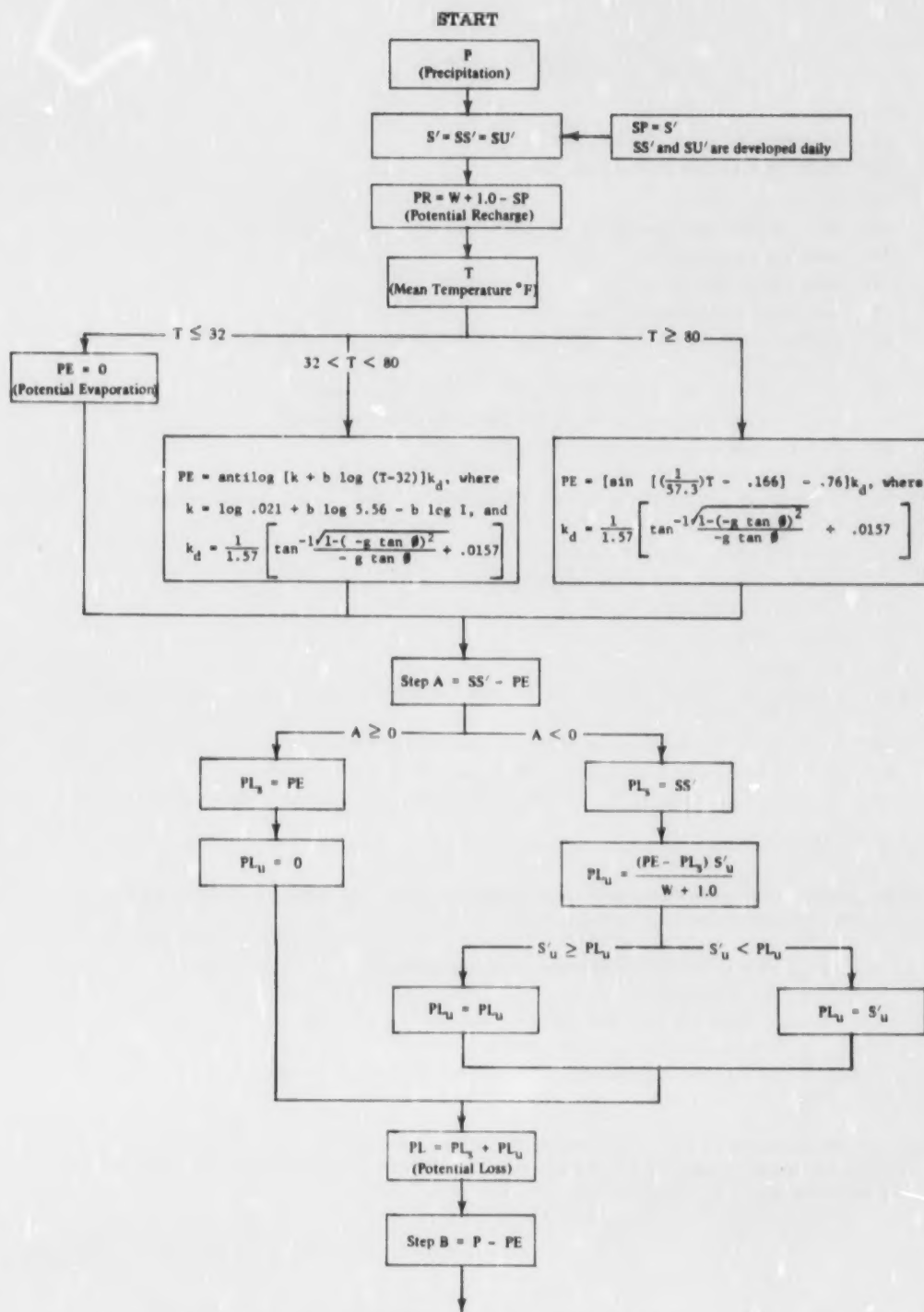


Fig. 4 Flow diagram for the modified Palmer program (EPA-2)

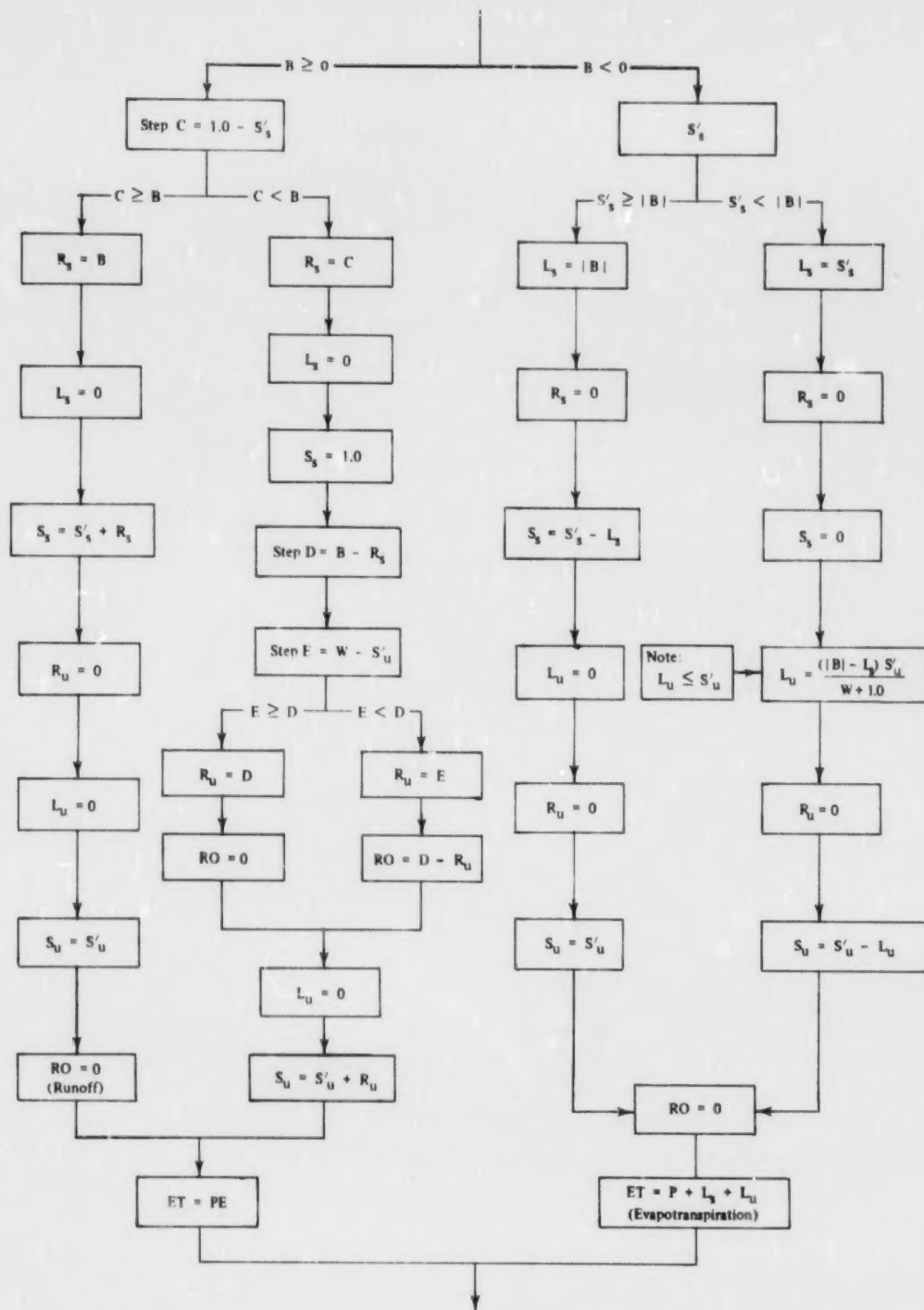
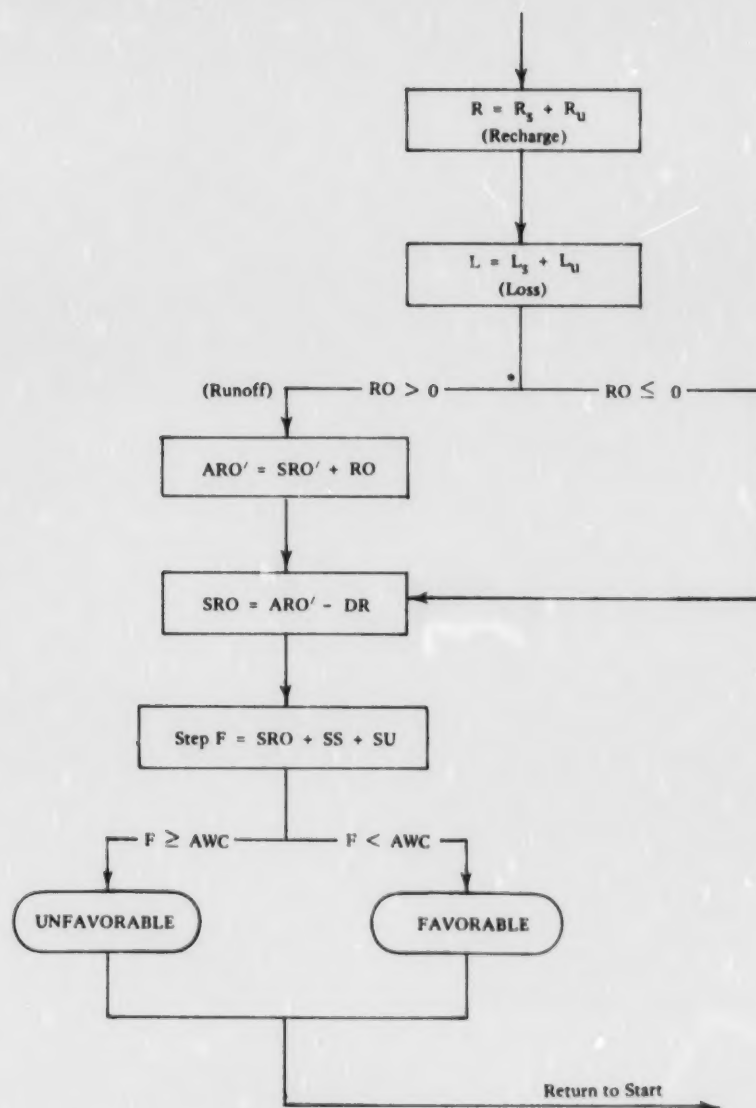


Fig. 4 Flow diagram for modified Palmer program (EPA-2) cont'd.



* The original Palmer program that computes the drought severity indices continues from this point and runs about as long as the portion shown here. Most of the constants for EPA-2 are stored on a separate tape at NCC; however, some values must be extracted from the earlier Palmer tabulations. This means that although there are no restrictions on the use or dissemination of the programs, a considerable amount of time and effort are required to collect the necessary material. In addition, a 20 to 25-year period of record can be processed at the Center for less than the cost of the program. Finally, the daily data must be purchased along with the program for each station of interest.

Fig. 4 Flow diagram for modified Palmer program (EPA-2) cont'd.

STATION	DATE	MM	HH	Y	P	SP	SS	SU	PE	PL	PR	R	L	ET	RJ	SRQ	UNF
223627	56	828	60	89	74.5	0.30	1.77	0.00	0.15	0.15	2.93	0.00	0.15	0.15	0.00	0.00	
223627	56	929	63	90	76.5	0.00	2.92	0.00	0.17	0.08	3.08	0.00	0.08	0.08	0.00	0.00	
223627	56	830	65	90	77.5	0.00	2.43	0.00	0.17	0.08	3.17	0.00	0.08	0.08	0.00	0.00	
223627	56	831	70	94	82.0	0.00	2.73	0.00	0.21	0.10	3.25	0.00	0.10	0.10	0.00	0.00	
223627	56	9	1	71	94	82.5	0.70	2.66	0.21	0.09	3.34	0.00	0.09	0.09	0.00	0.00	
223627	56	9	2	69	95	82.0	0.00	2.56	0.21	0.09	3.44	0.00	0.09	0.09	0.00	0.00	
223627	56	9	3	70	93	81.5	0.00	2.47	0.21	0.08	3.53	0.00	0.08	0.08	0.00	0.00	
223627	56	9	4	70	89	78.5	0.00	2.39	0.20	0.08	3.61	0.00	0.07	0.07	0.00	0.00	
223627	56	9	5	71	84	78.0	0.00	2.32	0.19	0.07	3.68	0.00	0.07	0.07	0.00	0.00	
223627	56	9	6	69	93	81.0	0.00	2.25	0.17	0.07	3.75	0.00	0.07	0.07	0.00	0.00	
223627	56	9	7	70	92	81.0	0.00	2.17	0.20	0.07	3.83	0.00	0.07	0.07	0.00	0.00	
223627	56	9	8	67	90	79.5	0.00	2.10	0.20	0.06	3.90	0.00	0.06	0.06	0.00	0.00	
223627	56	9	9	61	89	75.0	0.00	2.04	0.18	0.06	3.96	0.00	0.05	0.05	0.00	0.00	
223627	56	910	63	92	77.5	0.24	1.99	0.07	0.15	0.06	4.01	0.07	0.00	0.17	0.00	0.00	
223627	56	911	70	79	74.5	1.56	2.06	0.00	0.15	0.10	3.94	0.07	0.00	0.15	0.00	0.00	
223627	56	912	68	79	73.5	0.00	3.47	0.86	0.17	0.06	4.01	0.07	0.00	0.15	0.00	0.00	
223627	56	913	66	79	72.5	0.00	3.43	0.73	0.15	0.14	2.53	0.00	0.14	0.14	0.00	0.00	
223627	56	914	65	84	74.5	0.00	3.20	0.58	0.13	0.13	2.67	0.00	0.13	0.13	0.00	0.00	
223627	56	915	72	88	80.0	0.00	3.05	0.87	0.13	0.13	2.60	0.00	0.13	0.13	0.00	0.00	
223627	56	916	72	90	81.0	0.48	3.44	1.00	0.15	0.19	2.95	0.00	0.15	0.15	0.00	0.00	
223627	56	917	69	79	74.0	1.07	3.44	1.00	0.19	0.19	2.95	0.00	0.19	0.19	0.00	0.00	
223627	56	918	67	79	73.0	0.75	4.22	1.00	0.22	0.19	2.64	0.29	0.00	0.19	0.00	0.00	
223627	56	919	69	83	76.0	0.00	4.83	0.87	0.13	0.13	1.78	0.29	0.00	0.14	0.00	0.00	
223627	56	920	72	76	74.0	2.67	4.69	1.00	0.13	0.17	1.78	0.29	0.00	0.14	0.00	0.00	
223627	56	921	71	79	75.0	2.48	6.00	1.00	0.15	0.15	1.31	0.00	0.13	0.13	0.00	0.00	
223627	56	922	69	84	76.5	0.00	6.30	0.84	0.15	0.15	1.31	0.00	0.15	0.15	0.00	0.00	
223627	56	923	70	86	78.0	0.16	5.94	0.84	0.15	0.15	1.31	0.00	0.15	0.15	0.00	0.00	
223627	56	924	73	88	80.5	0.00	5.44	0.84	0.15	0.15	1.31	0.00	0.15	0.15	0.00	0.00	
223627	56	925	74	92	83.0	0.00	5.65	0.45	0.19	0.19	0.19	0.19	0.19	0.19	0.00	0.00	
223627	56	926	73	92	82.5	0.00	5.45	0.25	0.20	0.20	0.35	0.00	0.20	0.20	0.00	0.00	
223627	56	927	64	80	72.0	0.00	5.25	0.13	0.20	0.20	0.55	0.00	0.20	0.20	0.00	0.00	
223627	56	928	55	75	65.0	0.00	5.13	0.04	0.12	0.12	0.75	0.00	0.12	0.12	0.00	0.00	
223627	56	929	51	70	60.0	0.00	5.04	0.00	0.09	0.09	0.87	0.00	0.09	0.09	0.00	0.00	
223627	56	930	56	70	66.0	2.17	4.96	1.00	0.09	0.07	1.04	0.00	0.08	0.08	0.00	0.00	
223627	56	931	51	69	60.0	0.32	6.00	1.00	0.06	0.06	1.04	0.00	0.06	0.06	0.00	0.00	
223627	56	932	48	70	59.0	0.00	6.00	0.94	0.06	0.06	0.86	0.00	0.06	0.06	0.00	0.00	
223627	56	933	53	63	58.0	0.12	5.94	1.00	0.05	0.05	0.86	0.00	0.05	0.05	0.00	0.00	
223627	56	934	57	75	68.0	0.00	4.00	0.91	0.05	0.05	0.86	0.00	0.05	0.05	0.00	0.00	
223627	56	935	57	78	67.5	0.00	5.91	0.81	0.10	0.10	0.09	0.00	0.10	0.10	0.00	0.00	
223627	56	936	54	84	68.0	0.00	5.81	0.71	0.10	0.10	0.19	0.00	0.10	0.10	0.00	0.00	
223627	56	937	60	81	70.5	0.00	5.71	0.60	0.11	0.11	0.29	0.00	0.11	0.11	0.00	0.00	
223627	56	938	64	84	74.0	0.00	5.60	0.46	0.13	0.13	0.40	0.00	0.13	0.13	0.00	0.00	
223627	56	939	69	86	77.5	0.06	4.46	0.37	0.16	0.16	0.54	0.00	0.16	0.16	0.00	0.00	
223627	56	940	58	76	67.0	0.00	5.37	0.28	0.09	0.09	0.63	0.00	0.09	0.09	0.00	0.00	
223627	56	941	53	72	62.5	0.00	5.28	0.21	0.07	0.07	0.72	0.00	0.07	0.07	0.00	0.00	
223627	56	942	52	77	64.5	0.00	5.21	0.13	0.08	0.08	0.76	0.00	0.08	0.08	0.00	0.00	
223627	56	943	49	81	65.0	0.00	5.13	0.04	0.08	0.08	0.76	0.00	0.08	0.08	0.00	0.00	
223627	56	944	51	79	65.0	0.00	4.97	0.00	0.08	0.08	0.87	0.00	0.08	0.08	0.00	0.00	
223627	56	945	55	79	67.0	0.00	4.97	0.00	0.08	0.08	0.94	0.00	0.08	0.08	0.00	0.00	
223627	56	946	60	80	70.0	0.00	4.89	0.00	0.08	0.08	1.03	0.00	0.08	0.08	0.00	0.00	
223627	56	947	59	81	70.0	0.00	4.81	0.00	0.11	0.09	1.11	0.00	0.09	0.09	0.00	0.00	
223627	56	948	57	82	69.5	0.00	4.72	0.00	0.11	0.09	1.19	0.00	0.09	0.09	0.00	0.00	
223627	56	949	52	77	64.5	0.00	4.64	0.00	0.10	0.08	1.24	0.00	0.08	0.08	0.00	0.00	
223627	56	950	45	82.5	0.00	4.58	0.00	0.04	0.08	0.08	1.34	0.00	0.08	0.08	0.00	0.00	
223627	56	951	47	82	64.5	0.00	4.53	0.00	0.07	0.05	1.42	0.00	0.05	0.05	0.00	0.00	
223627	56	952	47	82	64.5	0.00	4.47	0.00	0.08	0.08	1.47	0.00	0.08	0.08	0.00	0.00	

STATION 223627 GREENWOOD, MS
 AWC= 6.0 DEPLETION RATE=0.75
 REG. RATE END DATE #DAYS
 490102 490110 9
 500105 500113 9
 511213 511222 10
 521230 521230 4
 530429 530506 8
 540428 540505 8
 550321 550328 8
 560212 560212 12
 571112 571124 13
 580417 581004 16
 590421 590421 5
 600301 600305 5
 611208 611219 12
 621224 621229 6
 631213 631224 12
 640422 640427 6
 650218 650212 5
 660309 660216 8
 671214 671221 8
 680103 680114 12
 691229 700102 5
 700105 700111 7
 710508 710514 7
 720101 720107 7
 730314 730325 12
 740919 740919 16
 MAX FOR TOTAL PERIOD OF RECORD

PERCENTILES DAYS
 0.05 14.7
 0.10 12.1
 0.25 11.5
 0.50 8.0

Fig. 5 Daily listing from EPA-2 for Greenwood, MS, Aug. - Oct. 1958, with summary table

STATION	DATE	MIN	MX	Y	P	SP	SS	SU	PE	PL	PR	R	L	ST	RD	SRD	UNF
STATION 456114 OLYMPIA, WA																	
AMC=12.0 DEPLETION RATE=0.75																	
REG. DATE	END. DATE	END. DATE	END. DATE	END. DATE	END. DATE	END. DATE	END. DATE	END. DATE	END. DATE	END. DATE	END. DATE	END. DATE	END. DATE	END. DATE	END. DATE	END. DATE	END. DATE
456114	4910 4	46 55	50.5	0.68	3.96	0.73	3.85	0.06	0.06	8.04	0.62	0.00	0.06	0.00	0.00	0.00	0.00
456114	4910 5	46 40	52.0	0.18	4.38	0.44	3.85	0.06	0.06	7.42	0.12	0.00	0.06	0.00	0.00	0.00	0.00
456114	4910 6	40 32	40.0	0.34	4.69	1.00	3.99	0.04	0.04	7.31	0.12	0.00	0.06	0.00	0.00	0.00	0.00
456114	4910 7	37 61	49.0	0.00	4.99	0.95	3.99	0.03	0.03	7.01	0.00	0.05	0.00	0.00	0.00	0.00	0.00
456114	4910 8	32 35	45.0	0.00	4.99	0.82	3.99	0.03	0.03	7.04	0.00	0.02	0.00	0.00	0.00	0.00	0.00
456114	4910 9	46 60	53.0	0.43	4.92	1.00	4.92	0.07	0.07	7.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00
456114	4910 10	42 37	49.5	0.19	5.28	1.00	4.62	0.05	0.05	6.72	0.00	0.00	0.00	0.00	0.00	0.00	0.00
456114	4910 11	45 60	52.5	0.31	5.42	1.00	4.62	0.06	0.06	6.58	0.00	0.00	0.00	0.00	0.00	0.00	0.00
456114	4910 12	36 63	49.5	0.00	5.66	0.95	4.66	0.03	0.03	6.34	0.00	0.04	0.00	0.00	0.00	0.00	0.00
456114	4910 13	32 58	45.0	0.00	5.61	0.81	4.66	0.04	0.04	6.39	0.00	0.05	0.00	0.00	0.00	0.00	0.00
456114	4910 14	30 60	47.5	0.00	5.97	0.66	4.66	0.05	0.05	6.43	0.00	0.05	0.00	0.00	0.00	0.00	0.00
456114	4910 15	29 61	50.0	0.04	5.93	0.85	4.66	0.05	0.05	6.47	0.00	0.01	0.00	0.00	0.00	0.00	0.00
456114	4910 16	30 61	50.0	0.00	5.91	0.81	4.66	0.04	0.04	6.49	0.00	0.04	0.00	0.00	0.00	0.00	0.00
456114	4910 17	27 59	49.0	0.00	5.98	0.81	4.66	0.02	0.02	6.52	0.00	0.00	0.00	0.00	0.00	0.00	0.00
456114	4910 18	27 50	38.5	0.00	5.47	0.79	4.66	0.02	0.02	6.53	0.00	0.01	0.00	0.00	0.00	0.00	0.00
456114	4910 19	22 52	37.0	0.00	5.46	0.78	4.66	0.01	0.01	6.56	0.00	0.02	0.00	0.00	0.00	0.00	0.00
456114	4910 20	22 55	38.0	0.00	5.44	0.76	4.66	0.02	0.02	6.56	0.00	0.02	0.00	0.00	0.00	0.00	0.00
456114	4910 21	29 58	43.5	0.00	5.43	0.73	4.66	0.03	0.03	6.57	0.00	0.03	0.00	0.00	0.00	0.00	0.00
456114	4910 22	29 53	41.0	0.00	5.40	0.71	4.66	0.03	0.03	6.63	0.00	0.03	0.00	0.00	0.00	0.00	0.00
456114	4910 23	35 49	42.0	0.00	5.97	0.68	4.66	0.05	0.05	6.66	0.00	0.03	0.00	0.00	0.00	0.00	0.00
456114	4910 24	37 60	48.5	0.02	5.94	0.66	4.66	0.05	0.05	6.66	0.00	0.03	0.00	0.00	0.00	0.00	0.00
456114	4910 25	31 43.5	0.01	5.92	0.63	0.00	4.66	0.03	0.03	6.68	0.00	0.02	0.00	0.00	0.00	0.00	0.00
456114	4910 26	31 43.5	0.01	5.92	0.63	0.00	4.66	0.04	0.04	6.70	0.21	0.00	0.04	0.00	0.00	0.00	0.00
456114	4910 27	35 48.0	0.25	5.90	0.86	0.00	4.66	0.06	0.06	6.80	0.21	0.00	0.06	0.00	0.00	0.00	0.00
456114	4910 28	35 52	44.0	1.44	5.90	1.00	5.85	0.06	0.06	6.80	0.21	0.00	0.06	0.00	0.00	0.00	0.00
456114	4910 29	40 57	48.5	1.36	6.69	1.00	6.99	0.06	0.06	6.80	0.21	0.00	0.06	0.00	0.00	0.00	0.00
456114	4910 30	40 57	48.5	0.01	7.69	0.96	6.99	0.05	0.05	6.80	0.21	0.00	0.06	0.00	0.00	0.00	0.00
456114	4910 31	36 63	49.5	0.00	7.93	0.92	6.99	0.05	0.05	6.93	0.00	0.04	0.05	0.00	0.00	0.00	0.00
456114	4910 32	36 74	53.0	0.00	7.90	0.85	6.99	0.07	0.07	6.93	0.00	0.04	0.05	0.00	0.00	0.00	0.00
456114	4911 1	35 65	50.0	0.00	7.84	0.80	6.99	0.05	0.05	6.96	0.00	0.03	0.00	0.00	0.00	0.00	0.00
456114	4911 2	34 72	53.0	0.00	7.79	0.74	6.99	0.06	0.06	6.96	0.00	0.04	0.06	0.00	0.00	0.00	0.00
456114	4911 3	33 71	52.0	0.00	7.73	0.69	6.99	0.05	0.05	6.97	0.00	0.07	0.07	0.00	0.00	0.00	0.00
456114	4911 4	38 74	56.0	0.00	7.68	0.62	6.99	0.07	0.07	6.97	0.00	0.05	0.05	0.00	0.00	0.00	0.00
456114	4911 5	35 64	49.5	0.00	7.61	0.57	6.99	0.03	0.03	6.99	0.00	0.03	0.03	0.00	0.00	0.00	0.00
456114	4911 6	35 64	49.5	0.00	7.61	0.57	6.99	0.03	0.03	6.99	0.00	0.03	0.03	0.00	0.00	0.00	0.00
456114	4911 7	36 52	44.0	0.00	7.59	0.54	6.99	0.04	0.04	6.97	0.00	0.04	0.04	0.00	0.00	0.00	0.00
456114	4911 8	35 53	46.5	0.19	7.53	0.70	6.99	0.04	0.04	6.97	0.00	0.04	0.04	0.00	0.00	0.00	0.00
456114	4911 9	40 48	44.0	0.14	7.68	0.91	6.99	0.04	0.04	6.92	0.00	0.03	0.03	0.00	0.00	0.00	0.00
456114	4911 10	42 50	46.0	0.18	7.68	1.00	7.35	0.04	0.04	6.92	0.00	0.03	0.03	0.00	0.00	0.00	0.00
456114	4911 11	46 53	49.5	1.16	8.85	1.00	8.46	0.05	0.05	6.93	0.00	0.04	0.04	0.00	0.00	0.00	0.00
456114	4911 12	45 49	47.0	2.89	9.46	1.00	11.00	0.04	0.04	6.93	0.00	0.04	0.04	0.00	0.00	0.00	0.00
456114	4911 13	45 49	47.0	0.11	12.00	1.00	11.00	0.05	0.05	6.93	0.00	0.04	0.04	0.00	0.00	0.00	0.00
456114	4911 14	45 56	50.5	0.19	13.00	1.00	11.00	0.05	0.05	6.93	0.00	0.04	0.04	0.00	0.00	0.00	0.00
456114	4911 15	45 56	50.5	0.00	13.00	0.96	11.00	0.05	0.05	6.93	0.00	0.04	0.04	0.00	0.00	0.00	0.00
456114	4911 16	40 54	47.0	0.00	11.49	0.91	11.00	0.03	0.03	6.93	0.00	0.01	0.01	0.00	0.00	0.00	0.00
456114	4911 17	37 35	46.0	0.04	11.81	0.92	11.00	0.03	0.03	6.93	0.00	0.01	0.01	0.00	0.00	0.00	0.00
456114	4911 18	45 55	50.0	0.04	11.82	0.91	11.00	0.03	0.03	6.93	0.00	0.01	0.01	0.00	0.00	0.00	0.00
456114	4911 19	46 51	48.5	0.00	11.81	0.87	11.00	0.04	0.04	6.99	0.00	0.04	0.04	0.00	0.00	0.00	0.00
456114	4911 20	38 56	47.0	0.00	11.87	0.82	11.00	0.04	0.04	6.99	0.00	0.04	0.04	0.00	0.00	0.00	0.00
456114	4911 21	36 50	47.0	0.00	11.83	0.86	11.00	0.03	0.03	6.93	0.00	0.03	0.03	0.00	0.00	0.00	0.00
456114	4911 22	37 51	44.0	0.88	11.46	1.00	11.00	0.03	0.03	6.93	0.00	0.03	0.03	0.00	0.00	0.00	0.00
456114	4911 23	44 52	50.0	0.36	12.00	1.00	11.00	0.04	0.04	6.90	0.00	0.02	0.02	0.00	0.00	0.00	0.00
456114	4911 24	50 40	53.0	0.36	12.00	1.00	11.00	0.06	0.06	6.90	0.00	0.02	0.02	0.00	0.00	0.00	0.00
456114	4911 25	48 59	53.5	2.46	13.00	1.00	11.00	0.05	0.05	6.93	0.00	0.03	0.03	0.00	0.00	0.00	0.00
456114	4911 26	43 56	49.5	1.00	12.00	1.00	11.00	0.04	0.04	6.93	0.00	0.02	0.02	0.00	0.00	0.00	0.00
456114	4911 27	43 56	49.5	1.00	12.00	1.00	11.00	0.04	0.04	6.93	0.00	0.02	0.02	0.00	0.00	0.00	0.00

STATION	DATE	MN	MX	T	P	SP	SS	SU	PE	PL	PR	R	L	ET	RD	SRD	UNF
456114	491128	41	52	46.3	0.54	12.00	1.00	11.00	0.03	0.03	0.00	0.02	0.00	0.03	0.31	1.66	X
456114	491129	40	47	43.5	0.34	12.00	1.00	11.00	0.03	0.03	0.00	0.02	0.00	0.03	0.31	1.22	X
456114	491130	42	51	48.5	0.18	12.00	1.00	11.00	0.03	0.03	0.00	0.02	0.00	0.03	0.15	0.62	X
456114	49112	1	47	53	0.72	12.00	1.00	11.00	0.04	0.04	0.00	0.02	0.00	0.04	0.68	0.55	X
456114	49112	2	33	49	0.44	12.00	1.00	11.00	0.02	0.02	0.00	0.02	0.00	0.02	0.42	0.22	X
456114	49112	3	20	41	0.01	12.00	1.00	11.00	0.01	0.01	0.00	0.02	0.00	0.01	0.00	0.00	X
456114	49112	4	29	51	0.02	12.00	1.00	11.00	0.02	0.02	0.00	0.02	0.00	0.02	0.00	0.00	X
456114	49112	5	35	48	0.46	12.00	1.00	11.00	0.02	0.02	0.00	0.02	0.00	0.02	0.44	0.00	X
456114	49112	6	29	45	0.00	12.00	0.99	11.00	0.01	0.01	0.00	0.02	0.00	0.01	0.00	0.00	014
456114	49112	7	26	46	0.00	11.99	0.98	11.00	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.00	X
456114	49112	8	25	44	0.02	11.98	1.00	11.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	X
456114	49112	9	27	46	0.00	12.00	0.99	11.00	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.00	X
456114	491210	24	33	33.5	0.00	11.99	0.99	11.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	X
456114	491211	26	34	30.0	0.05	11.99	1.00	11.00	0.00	0.00	0.01	0.00	0.00	0.00	0.04	0.00	X
456114	491212	32	38	35.0	0.19	12.00	1.00	11.00	0.01	0.01	0.00	0.00	0.00	0.01	0.18	0.00	X
456114	491213	36	43	39.5	0.06	12.00	1.00	11.00	0.02	0.02	0.00	0.00	0.00	0.02	0.04	0.00	X
456114	491214	37	47	42.0	0.00	12.00	0.98	11.00	0.02	0.02	0.00	0.00	0.00	0.02	0.00	0.00	003
456114	491215	36	43	39.5	0.07	11.98	1.00	11.00	0.02	0.02	0.02	0.00	0.02	0.02	0.00	0.00	X
456114	491216	32	40	38.0	0.20	12.00	1.00	11.00	0.01	0.01	0.00	0.00	0.00	0.02	0.03	0.00	X
456114	491217	32	44	38.0	0.89	12.00	1.00	11.00	0.01	0.01	0.00	0.00	0.00	0.01	0.19	0.00	X
456114	491218	26	37	31.5	0.24	12.00	1.00	11.00	0.00	0.00	0.00	0.00	0.00	0.01	0.68	0.00	X
456114	491219	17	34	25.5	0.00	12.00	1.00	11.00	0.00	0.00	0.00	0.00	0.00	0.00	0.24	0.00	X
456114	491220	22	37	29.5	0.13	12.00	1.00	11.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	X
456114	491221	36	44	40.0	0.13	12.00	1.00	11.00	0.02	0.02	0.00	0.00	0.00	0.00	0.13	0.00	X
456114	491222	42	49	45.5	0.31	12.00	1.00	11.00	0.03	0.03	0.00	0.00	0.00	0.02	0.11	0.00	X
456114	491223	40	47	43.5	1.27	12.00	1.00	11.00	0.02	0.02	0.00	0.00	0.00	0.02	0.28	0.00	X
456114	491224	33	49	41.0	0.00	12.00	0.98	11.00	0.02	0.02	0.00	0.00	0.00	0.02	1.25	0.50	009
456114	491225	37	49	43.0	0.66	11.98	1.00	11.00	0.02	0.02	0.02	0.00	0.02	0.02	0.00	0.00	X
456114	491226	39	43	41.0	0.78	12.00	1.00	11.00	0.02	0.02	0.00	0.00	0.00	0.02	0.00	0.00	X
456114	491227	42	48	45.0	2.94	12.00	1.00	11.00	0.03	0.03	0.00	0.00	0.00	0.02	0.76	0.01	X
456114	491228	46	52	49.0	0.20	12.00	1.00	11.00	0.04	0.04	0.00	0.00	0.00	0.03	2.91	2.17	X
456114	491229	51	51	41.0	0.42	12.00	1.00	11.00	0.02	0.02	0.00	0.00	0.00	0.04	0.16	1.58	X
456114	491230	31	36	33.5	0.34	12.00	1.00	11.00	0.00	0.00	0.00	0.00	0.00	0.02	0.40	1.24	X
456114	491231	30	42	36.0	0.18	12.00	1.00	11.00	0.01	0.01	0.00	0.00	0.00	0.00	0.54	1.02	X
456114	50	1	20	33	0.10	12.00	1.00	11.00	0.00	0.00	0.00	0.00	0.00	0.01	0.17	0.43	X
456114	50	1	2	6	23	0.06	12.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.00	X
456114	50	1	3	5	28	0.11	12.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.00	X
456114	50	1	4	23	32	0.00	12.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.00	X
456114	50	1	5	24	37	0.04	12.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	X
456114	50	1	6	34	37	0.86	12.00	1.00	0.01	0.01	0.00	0.00	0.00	0.00	0.04	0.00	X
456114	50	1	7	32	36	0.46	12.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	X
456114	50	1	8	30	34	0.04	12.00	1.00	0.00	0.00	0.00	0.00	0.00	0.01	0.85	0.10	X
456114	50	1	9	28	37	0.04	12.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	X
456114	50	110	31	39	0.26	12.00	1.00	11.00	0.00	0.00	0.00	0.00	0.00	0.00	0.26	0.00	X
456114	50	111	27	36	0.09	12.00	1.00	11.00	0.01	0.01	0.00	0.00	0.00	0.01	0.75	0.00	X
456114	50	112	18	32	0.11	12.00	1.00	11.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.00	X
456114	50	113	12	19	1.21	12.00	1.00	11.00	0.00	0.00	0.00	0.00	0.00	0.00	1.21	0.00	X
456114	50	114	6	21	13.5	0.07	12.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.00	X
456114	50	115	18	25	21.5	0.19	12.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.19	0.00	X
456114	50	116	16	34	25.0	0.01	12.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	X
456114	50	117	8	26	17.0	0.00	12.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	X
456114	50	118	13	28	19.5	0.38	12.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.38	0.00	X
456114	50	119	24	41	32.5	1.89	12.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	1.89	1.14	X
456114	50	120	38	46	42.0	1.07	12.00	1.00	0.02	0.02	0.00	0.00	0.00	0.02	1.05	1.44	X
456114	50	121	42	48	45.0	0.73	12.00	1.00	0.03	0.03	0.00	0.00	0.00	0.03	0.70	1.39	X

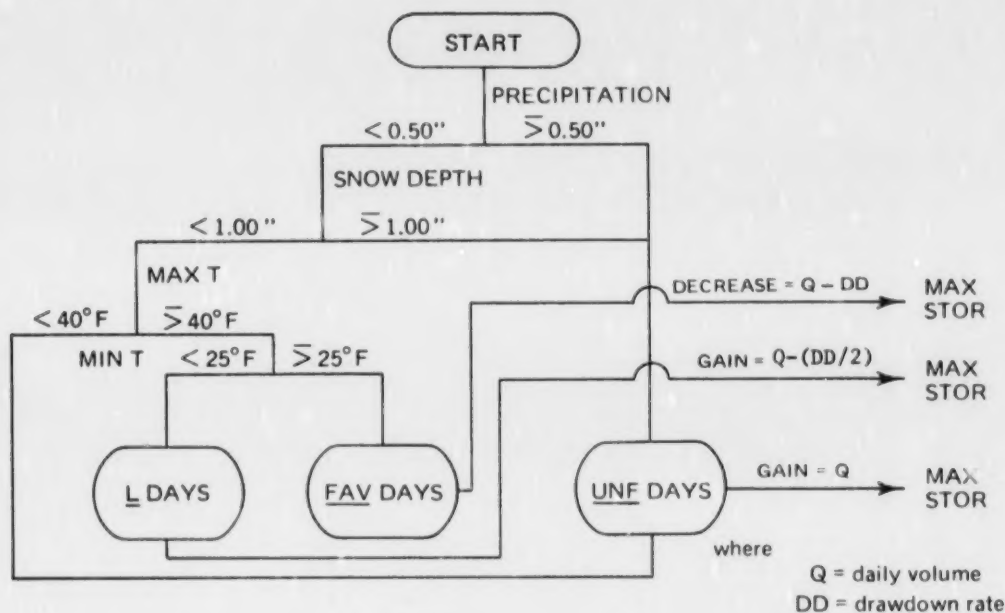
Fig. 7 Daily listing from EPA-2 for Olympia, WA, Nov. 1949 - Jan. 1950

STATION	AMC	YEARS	MO/YR	MAX	5%	10%	25%	50%	STATION	AMC	YEARS	MO/YR	MAX	5%	10%	25%	50%
ALABAMA									MISSISSIPPI								
BAY MINETTE,AL	6	1949-73	MAR 62	13	13	13	9	7	GREENWOOD,MS	6	1949-73	SEP 58	16	15	12	12	8
BREWTON,AL	6	1949-73	MAY 70	17	16	11	8	7	JACKSON,MS	6	1943-61	DEC 61	12	12	10	8	7
CLANTON,AL	6	1949-73	DEC 61	24	20	11	9	7	MERIDIAN,MS	6	1948-73	FEB 61	14	13	11	8	7
MOBILE,AL	6	1949-73	APR 55	15	14	11	10	7	PONTOTOC,MS	6	1949-71	DEC 67	20	19	14	12	9
SELMA,AL	6	1949-73	DEC 61	20	18	11	8	6	POPLARVILLE,MS	6	1943-73	DEC 61	25	22	13	8	6
THOMASVILLE,AL	6	1953-74	DEC 61	25	23	13	10	8	STONEVILLE,MS	6	1951-72	APR 58	17	17	15	12	7
ARKANSAS									VICKSBURG,MS	6	1942-62	DEC 61	17	17	14	10	7
DUMAS,AR	6	1951-71	APR 58	19	19	14	10	7	NORTH CAROLINA								
LITTLE ROCK,AR	6	1949-72	MAY 68	12	12	12	9	7	CHARLOTTE,NC	6	1949-73	JAN 73	12	12	11	8	6
CALIFORNIA									RALEIGH,NC	6	1949-73	JAN 63	14	13	12	7	6
LOS ANGELES,CA	7	1952-69	FEB 69	5	5	3	1	0	WELDON,NC	6	1926-50	JAN 30	11	11	10	7	5
SAN FRANCISCO,CA	7	1949-72	JAN 69	13	13	11	5	4	WILMINGTON,NC	6	1949-73	JUL 50	11	10	9	8	6
FLORIDA									OREGON								
AVON PARK,FL	6	1945-72	JUN 68	13	12	9	7	4	EUGENE,OR	12	1948-73	JAN 49	35	34	31	21	15
BELLE GLADE,FL	6	1951-73	OCT 52	11	10	8	8	6	MEDFORD,OR	12	1948-72	DEC 64	21	19	11	5	3
DAYTONA BEACH,FL	6	1955-73	SEP 64	8	8	8	6	4	ROSEBURG,OR	12	1935-64	JAN 50	22	20	18	12	9
TAMPA,FL	6	1953-73	JUL 60	16	15	9	6	3	SALEM,OR	12	1948-73	DEC 49	36	34	25	17	13
GEORGIA									SOUTH CAROLINA								
AUGUSTA,GA	6	1949-72	FEB 71	10	10	9	6	4	CHARLESTON,SC	6	1948-73	JUN 73	24	21	11	6	5
MACON,GA	6	1949-72	JAN 64	12	11	9	7	5	COLUMBIA,SC	6	1949-73	JAN 63	15	14	9	7	5
SAVANNAH,GA	6	1949-72	SEP 50	17	16	11	7	4	CONWAY,SC	6	1945-73	JAN 70	9	9	9	7	6
LOUISIANA									TENNESSEE								
HOUMA,LA	6	1950-73	MAY 59	17	16	11	8	6	CROSSVILLE,TN	6	1953-73	JAN 66	24	24	22	20	17
LAFAYETTE,LA	6	1948-73	JAN 59	12	12	10	8	6	TEXAS								
LAKE PROVIDENCE,LA	6	1951-72	DEC 67	19	18	14	12	7	ABILENE,TX	6	1950-70	JAN 61	6	6	6	3	0
LEESVILLE,LA	6	1950-73	APR 53	35	31	16	8	6	AMARILLO,TX	6	1949-71	FEB 60	11	10	8	2	0
MURFREESBORO,LA	6	1949-72	DEC 61	12	12	12	8	7	BROWNSVILLE,TX	6	1954-72	SEP 67	12	11	6	2	0
NEW ORLEANS,LA	6	1954-73	MAY 59	16	16	9	7	6	CORPUS CHRISTI,TX	6	1951-72	SEP 67	13	11	5	3	1
ST. JOSEPH,LA	6	1956-73	DEC 61	12	11	11	9	6	DALLAS,TX	6	1948-72	APR 66	15	15	12	7	4
SCHRIEVER,LA	6	1948-73	MAR 48	16	15	13	8	7	HOUSTON,TX	6	1948-72	OCT 49	14	13	9	7	4
SHREVEPORT,LA	6	1949-72	JAN 68	11	11	9	7	6	WICHITA FALLS,TX	6	1950-72	APR 57	8	8	6	3	3
WINNFIELD,LA	6	1950-73	MAY 53	16	16	14	11	6	WASHINGTON								
MISSISSIPPI									LONGVIEW,WA	12	1948-73	DEC 49	60	53	35	21	17
ABERDEEN,MS	6	1951-72	DEC 61	24	23	13	9	7	OLYMPIA,WA	12	1949-73	DEC 49	65	58	38	30	21
BLOXTON,MS	6	1951-73	SEP 57	14	13	10	8	7	SEATTLE,WA	7	1949-73	DEC 49	47	40	24	14	11
CANTON,MS	6	1948-73	DEC 61	15	11	8	6	6	SFOUIM	12	1948-73	MAR 56	6	5	3	0	0
CLARKSDALE,MS	6	1949-72	DEC 72	18	16	11	10	8	VANCOUVER,WA	12	1924-50	JAN 50	31	28	19	17	11
COLUMBIA,MS	6	1947-73	FEB 61	33	27	16	10	8	WALLA WALLA,WA	7	1950-73	JAN 69	14	14	10	6	0

Fig. 9 Storage days estimated from EPA-2 program

SUMMARY TABLE FROM NCC-EPA-3 PROGRAM

A summary of each winter season examined shows the Freeze Index, its duration and the maximum storage days computed from the daily listings. Additional information includes the mean number of storage days, the standard deviation, unbiased third moment about the mean, the coefficient of skewness and a list of the thresholds used for each of the elements examined. The thresholds may be changed to fit individual systems or other special conditions. Storage days are also computed for recurrence intervals of 5, 10, 25 & 50—years using the Pearson Type III method. The procedure used to define each day and to compute the coefficient of skewness is shown below;



1. Using the values in the "MAX STOR" column, compute the mean storage days ($\bar{x}$) and the standard deviation (σ).
2. Cube the difference between each storage value and the mean $(\text{STOR} - \bar{x})^3$ and sum algebraically.
3. Compute the unbiased third moment about the mean:
$$a = \frac{N \sum (\text{STOR} - \bar{x})^3}{(N-1)(N-2)}$$
4. Compute the coefficient of skewness:
$$C_s = \frac{a}{\sigma^3}$$
5. Enter table with C_s and recurrence interval to find k .
6. Storage days are then equal to $\bar{x} + k\sigma$.

Fig. 11 Outline of the procedure used in developing the summary table for EPA-3 shown in Fig. 12

USE OF CLIMATIC DATA IN DESIGN OF SOILS TREATMENT SYSTEMS
 STA # 485390 LANDER, WY HIGH TO LOW FREEZE INDEX
 TABLE 1 EPA-3
 PORI 481101-740430 05/13/76

INDEX	BEGIN DATE	END DATE	DUR	MAX FA	MAX UNF	MAX STOR	MAX (STOR-MN)	MAX (STOR-MN)3
2154	721110	730410	151	7	149	169.00	64.24	265104
1880	481103	490314	131	16	109	128.00	23.24	12552
1704	611101	620316	135	14	103	123.50	18.74	6581
1397	671101	680218	109	10	105	129.75	24.99	15606
1286	551110	560315	125	19	46	109.00	4.24	76
1230	591103	600317	134	39	98	126.50	21.74	10275
1156	631206	640328	112	19	102	121.00	16.24	4283
1075	511113	520325	132	28	48	106.75	1.99	8
1035	541127	550328	121	27	59	111.00	6.24	243
1010	711101	720315	106	21	112	114.75	9.99	997
1005	581114	590315	121	10	47	123.75	18.99	6848
985	681123	690315	112	12	29	104.25	-51	0
883	621219	630317	88	14	42	73.50	-31.26	-30547
879	561113	570207	86	14	58	101.25	-3.51	-43
863	641110	650328	138	17	24	88.00	-16.76	-4708
836	491202	500214	74	35	48	73.00	-31.76	-32036
822	731118	740225	99	15	31	90.75	-14.01	-2750
812	651211	660307	86	23	45	87.25	-17.51	-5369
752	601102	610308	126	10	78	115.25	10.49	1154
733	521115	530306	111	11	40	102.00	-2.76	-21
698	701209	710307	88	16	44	81.50	-23.26	-12584
664	571101	580320	139	13	50	115.50	10.74	1239
560	501107	510319	132	9	18	77.75	-27.01	-19705
495	661130	670308	98	15	25	82.00	-22.76	-11790
413	691116	700404	139	13	25	90.25	-14.51	-3055
	531117	540331	134	17	14	78.50	-26.26	-18109

STORAGE DATA N = 26 MEAN = 104.76 SD = 22.45 A = 7984 (STOR-MN)3 = 184249 CS = .70

AVERAGE INDEX 1026

PERCENTILES

MAX 2154
 5% 2044
 10% 1757
 25% 1241
 50% 934

THRESHOLDS 1 32 F, 1 DEPTH, .50 PRECIP, 1.50 RATE < 25 F, MIN < 40 F, MAX

RECURRENT INTV
 STOR05 = 122.50
 STOR10 = 134.69
 STOR25 = 148.93
 STOR50 = 158.81

Fig. 12 Summary of 26 winter seasons at Lander, WY from the EPA-3 program (see Figs. 13-18 for the daily listings)

USE OF CLIMATIC DATA IN DESIGN OF SOILS TREATMENT SYSTEMS

EPA-3
PDR 481101-740430
05/13/76

STA # 485390 LANDER, WY

[illegible]

Fig. 13 Listing of daily data from EPA-3 program, Lander, WY, November 1948

USE OF CLIMATIC DATA IN DESIGN OF SOILS TREATMENT SYSTEMS														
STA # 485390 LANDER, WY														
EPA-3														
PDR1 481101-740430														
05/13/76														
YR	MO	DA	MAX	MIN	MEAN	SNOW DPTH	PPPP	FGG	DD	CDD	FA	DUR FA	DUR UNE	MAX STDR
48	12	01	33	16	25	2			-7	-96			X	20.50
48	12	02	52	17	35	1			3	-93			X	21.50
48	12	03	48	38	43	1			11	-82			X	22.50
48	12	04	40	7	24	2			-8	-90			X	23.50
48	12	05	26	0	13	3	.24		-19	-109			X	24.50
48	12	06	31	8	20	3			-12	-121			X	25.50
48	12	07	24	5	15	3			-17	-138			X	26.50
48	12	08	32	9	21	2			-11	-149			X	27.50
48	12	09	35	3	19	2			-13	-162			X	28.50
48	12	10	40	19	30	2			-2	-164			X	29.50
48	12	11	40	22	31	2			-1	-165			X	30.50
48	12	12	43	29	36	1			-4	-161			X	31.50
48	12	13	34	21	28	1			-4	-165			X	32.50
48	12	14	23	16	20	1			-12	-177			X	33.50
48	12	15	26	10	18	1	.01		-14	-191			X	34.50
48	12	16	23	5	14	1			-18	-209			X	35.50
48	12	17	21	3	12	1			-20	-229			X	36.50
48	12	18	27	7	17	1			-15	-244			X	37.50
48	12	19	34	14	24	1			-8	-252			X	38.50
48	12	20	42	17	30	1			-2	-254			X	39.50
48	12	21	25	6	16	1			-16	-270			X	40.50
48	12	22	22	1	12	1			-20	-290			X	41.50
48	12	23	17	11	14	2			-18	-308			X	42.50
48	12	24	18	0	9	6	.32	F	-23	-331			X	43.50
48	12	25	3	-14	-6	6	.02	F	-38	-369			X	44.50
48	12	26	5	-17	-6	6			-38	-407			X	45.50
48	12	27	15	-12	2	5			-30	-437			X	46.50
48	12	28	32	7	20	5			-12	-449			X	47.50
48	12	29	19	3	11	4			-21	-470			X	48.50
48	12	30	27	1	14	3			-18	-488			X	49.50
48	12	31	23	1	12	3			-20	-508			X	50.50

Fig. 14 Listing of daily data from EPA-3 program, Lander, WY, December 1948

USE OF CLIMATIC DATA IN DESIGN OF SOILS TREATMENT SYSTEMS														EPA-3			05/13/76		
STA # 485390 LANDER, WY														PORI 481101-740430			DUR		
YR	MO	DA	MAX	MIN	MEAN	SNOW DPTH	PPPP	FOG	DD	CDD	FA	DUR FA	UNF	DUR UNF	MAX STOR				
49	01	01	23	3	13	3			-19	-527			X		51.50				
49	01	02	21	7	14	6	.10		-18	-545			X		52.50				
49	01	03	8	1	5	7	.21	F	-27	-572			X		53.50				
49	01	04	16	1	9	9	.05		-23	-595			X		54.50				
49	01	05	25	1	13	8			-19	-614			X		55.50				
49	01	06	22	-2	10	8			-22	-636			X		56.50				
49	01	07	23	3	13	7			-19	-655			X		57.50				
49	01	08	30	-1	15	7	.07	F	-17	-672			X		58.50				
49	01	09	-1	-15	-8	9	.11		-40	-712			X		59.50				
49	01	10	-1	-15	-8	10	.09		-40	-752			X		60.50				
49	01	11	7	-8	-1	10	.07		-33	-785			X		61.50				
49	01	12	5	-14	-5	9		F	-37	-822			X		62.50				
49	01	13	13	0	7	9		F	-25	-847			X		63.50				
49	01	14	35	3	19	9		F	-13	-860			X		64.50				
49	01	15	25	12	19	9	.04		-13	-873			X		65.50				
49	01	16	18	-5	7	9			-25	-898			X		66.50				
49	01	17	6	-12	-3	9			-35	-933			X		67.50				
49	01	18	18	-5	7	9	.02		-25	-958			X		68.50				
49	01	19	5	-12	-4	9			-36	-994			X		69.50				
49	01	20	-5	-21	-13	9			-45	-1039			X		70.50				
49	01	21	14	-19	-6	9			-38	-1077			X		71.50				
49	01	22	7	0	7	10	.24		-25	-1102			X		72.50				
49	01	23	1	-23	-11	17	.26		-43	-1145			X		73.50				
49	01	24	-12	-31	-22	17			-54	-1199			X		74.50				
49	01	25	-8	-31	-20	17			-52	-1251			X		75.50				
49	01	26	2	-25	-12	17			-44	-1295			X		76.50				
49	01	27	10	-16	-3	16	.22		-35	-1330			X		77.50				
49	01	28	13	-7	3	19	.14		-29	-1359			X		78.50				
49	01	29	2	-15	-7	17			-39	-1398			X		79.50				
49	01	30	14	-8	3	15			-29	-1427			X		80.50				
49	01	31	13	-7	3	15	.03		-29	-1456			X		81.50				

Fig. 15 Listing of daily data from EPA-3 program, Lander, WY, January 1949

USE OF CLIMATIC DATA IN DESIGN OF SOILS TREATMENT SYSTEMS										EPA-3			05/13/76		
STA # 485300 LANDER, WY										PORT 481101-740430					
YR	MO	DA	MAX	MIN	MEAN	SNOW DPTH	P-PP	FUG	DD	CCD	FA	DUR FA	UNF	DUR UNF	MAX STUR
49	02	01	-2	-17	-10	15			-42	-1498			X		82.50
49	02	02	-1	-19	-10	15			-42	-1540			X		83.50
49	02	03	2	-19	-9	15			-41	-1581			X		84.50
49	02	04	25	-14	6	15			-26	-1607			X		85.50
49	02	05	21	2	12	15			-20	-1627			X		86.50
49	02	06	25	-6	10	15			-22	-1649			X		87.50
49	02	07	27	9	18	15	.01		-14	-1663			X		88.50
49	02	08	22	5	14	15			-18	-1681			X		89.50
49	02	09	30	2	16	14			-16	-1697			X		90.50
49	02	10	46	11	29	10			-3	-1700			X		91.50
49	02	11	38	6	22	10	.15		-10	-1710			X		92.50
49	02	12	6	-16	-5	12	.23		-37	-1747			X		93.50
49	02	13	7	-28	-11	12			-43	-1790			X		94.50
49	02	14	18	-8	5	11			-27	-1817			X		95.50
49	02	15	32	1	17	11			-15	-1832			X		96.50
49	02	16	44	8	26	10			-6	-1838			X		97.50
49	02	17	50	22	36	9			4	-1834			X		98.50
49	02	18	49	32	41	8			9	-1825			X		99.50
49	02	19	46	26	36	6			4	-1821			X		100.50
49	02	20	36	17	27	6			-5	-1826			X		101.50
49	02	21	42	21	32	5			0	-1826			X		102.50
49	02	22	47	20	34	5			2	-1824			X		103.50
49	02	23	45	25	35	3			3	-1821			X		104.50
49	02	24	37	15	26	2			-6	-1827			X		105.50
49	02	25	43	17	30	2			-2	-1829			X		106.50
49	02	26	39	23	31	2			-1	-1830			X		107.50
49	02	27	38	19	29	2			-3	-1833			X		108.50
49	02	28	40	17	29	2			-3	-1836			X		109.50

Fig. 16 Listing of daily data from EPA-3 program, Lander, WY, February 1949

USE OF CLIMATIC DATA IN DESIGN OF SOILS TREATMENT SYSTEMS															EPA-3		05/13/75	
STA # 485390 LANDER, WY															PDR 481101-74C430			
YR	MO	DA	MAX	MIN	MEAN	SNOW DPTH	PPPP	FDG	DD	COD	FA	DUR FA	UNF	JUR UNF	MAX STLR			
49	03	01	43	18	31	2			-1	-1837			X		110.50			
49	03	06	49	25	37	1			5	-1832			X		111.50			
49	03	07	46	25	36	1			4	-1828			X		112.50			
49	03	08	36	27	32	1	.07		0	-1828			X		113.50			
49	03	09	44	18	31	1			-1	-1829			X		114.50			
49	03	10	36	18	27	1			-5	-1834			X		115.50			
49	03	11	40	22	31	T			-1	-1835			L	109	115.75			
49	03	12	39	25	32	T	.05		0	-1835		1	X		116.75			
49	03	13	49	23	36	T			4	-1831			L	1	117.00			
49	03	14	32	11	22	T			-10	-1841		1	X		118.00			
49	03	15	53	13	33	T			1	-1840			L	1	118.25			
49	03	16	39	25	32	T			0	-1840		1	X		119.25			
49	03	17	51	21	36	T			4	-1836		1	X		119.50			
49	03	18	54	27	41	T			9	-1827			L		119.50			
49	03	19	62	30	46	T			14	-1813	X		X		119.00			
49	03	20	57	30	44	T			12	-1801	X		X		118.50			
49	03	21	50	25	38		.25		6	-1795	X		X		118.00			
49	03	22	50	28	39				7	-1788	X		X		117.50			
49	03	23	37	28	33	7	1.19		1	-1787		6			117.00			
49	03	24	32	20	26	13	.10		-6	-1793	X		X		118.00			
49	03	25	40	12	26	7			-6	-1799	X		X		119.00			
49	03	26	41	22	32	4			0	-1799	X		X		120.00			
49	03	27	42	20	31	3			-1	-1800	X		X		121.00			
49	03	28	33	14	24	3	.04		-8	-1808	X		X		122.00			
49	03	29	29	21	25	4	.17		-7	-1815	X		X		123.00			
49	03	30	39	18	29	1			-3	-1818	X		X		124.00			
49	03	31	39	23	31	1	.01		-1	-1819	X		X		125.00			
															126.00			

Fig. 17 Listing of daily data from EPA-3 program, Lander, WY, March 1949

USE OF CLIMATIC DATA IN DESIGN OF SOILS TREATMENT SYSTEMS										EPA-3			05/13/76		
STA # 485390 LANDER, WY										PDR 481101-740430					
YR	MO	DA	MAX	MIN	MEAN	SNOW DPTH	PPPP	FOG	DD	CDD	FA	DUR FA	UNF	DUR UNF	MAX STOR
49	04	01	41	23	32	1			0	-1819			X		127.00
49	04	02	46	22	34	1			2	-1817			X		128.00
49	04	03	51	32	42	T			10	-1807				11	127.50
49	04	04	57	31	44	T			12	-1795					127.00
49	04	05	60	32	46				14	-1781					126.50
49	04	06	62	31	47				15	-1766					126.00
49	04	07	67	35	51				19	-1747					125.50
49	04	08	58	37	48		.32		16	-1731					125.00
49	04	09	47	32	40				8	-1723					124.50
49	04	10	59	27	43				11	-1712					124.00
49	04	11	73	34	54				22	-1690					123.50
49	04	12	63	40	52				20	-1670					123.00
49	04	13	49	32	41	T	.15		9	-1661					122.50
49	04	14	39	29	34	T	.48	F	2	-1659	11		X		123.50
49	04	15	59	23	41				9	-1650			L	1	123.75
49	04	16	68	35	52				20	-1630					123.25
49	04	17	64	37	51				19	-1611					122.75
49	04	18	69	34	52				20	-1591					122.25
49	04	19	70	39	55				23	-1568					121.75
49	04	20	60	38	49				17	-1551					121.25
49	04	21	66	34	50				18	-1533					120.75
49	04	22	64	40	52				20	-1513					120.25
49	04	23	75	41	58				26	-1487					119.75
49	04	24	78	50	64				32	-1455					119.25
49	04	25	70	45	58				26	-1429					118.75
49	04	26	65	42	54				22	-1407					118.25
49	04	27	71	40	56				24	-1383					117.75
49	04	28	77	42	60				28	-1355					117.25
49	04	29	69	42	56		.04		24	-1331					116.75
49	04	30	55	35	45				13	-1318		16			116.25
FREEZE INDEX			1880		481103	490314	131					16		109	128.00

Fig. 18 Listing of daily data from EPA-3 program, Lander, WY, April 1949

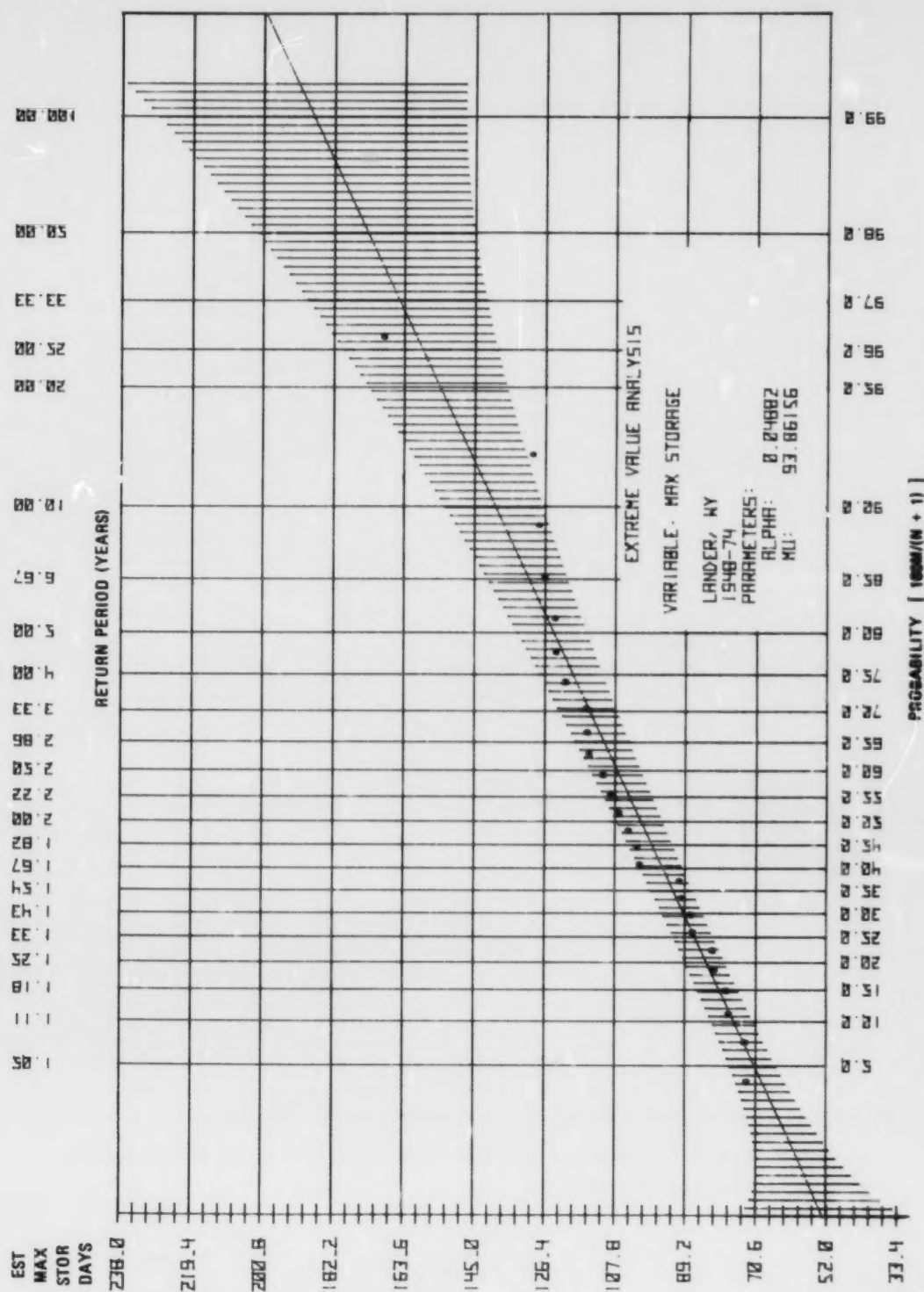


Fig. 18A Estimated maximum annual storage days for return periods to 100 years (Gumbel)

STATION	5-YR	10-YR	25-YR	50-YR	PERIOD	DD
BELLE PLAINE, IA	104.3	112.7	121.9	128.0	11/48-04/73	1.50
DES MOINES, IA	98.3	105.8	113.9	119.1	11/48-04/73	1.50
GRINNELL, IA	102.1	110.0	118.8	124.7	11/48-04/73	1.50
HAMPTON, IA	121.2	130.6	141.2	148.4	11/49-04/72	1.50
INDIANOLA, IA	85.5	93.9	103.1	109.2	11/48-04/73	1.50
KEOSAUQUA, IA	77.2	84.9	93.5	99.3	11/48-04/73	1.50
KNOXVILLE, IA	87.4	96.8	107.5	114.7	11/49-04/70	1.50
LOGAN, IA	93.1	105.6	110.6	116.5	11/47-04/73	1.50
NEWTON, IA	97.6	106.9	116.9	123.5	11/52-04/72	1.50
OSCEOLA, IA	79.1	87.3	96.3	102.3	11/48-04/67	1.50
OSKALOUSA, IA	90.8	99.1	108.3	114.4	11/46-04/73	1.50
SHENANDOAH, IA	75.3	83.3	92.0	97.7	11/48-04/73	1.50
WINTERSET, IA	96.5	105.4	115.0	121.2	11/53-04/73	1.50
BALTIMORE, MD	51.8	57.4	63.4	67.3	11/50-04/72	1.25
BALTIMORE, MD	48.8	54.8	61.4	65.7	11/50-04/72	1.33
BALTIMORE, MD	43.0	49.9	57.7	63.0	11/50-04/72	1.50
CROSSVILLE, TN	48.3	53.9	60.1	64.3	11/53-04/73	1.50
DIVERSION DAM, WY	80.7	88.8	98.0	104.7	11/48-04/74	1.50
LANDER, WY	122.5	134.7	148.9	158.8	11/48-04/74	1.50
PAVILLION, WY	85.3	92.4	100.1	105.2	11/48-04/74	1.50
RIVERTON, WY	100.2	105.7	111.6	115.5	11/47-04/74	1.50
RIVERTON, WY	102.1	110.3	119.5	125.8	11/22-04/47	1.50

Table 4 Estimated storage days for indicated return periods from the EPA-3 program.

Note the effect of changing the drawdown rate (DD) at Baltimore and the period of record at Riverton.

APPENDIX B.

SUPPLEMENTAL INFORMATION

The tables in Figure 42 show the calendar dates in spring (in fall) after which (before which) threshold temperatures, or lower, may be expected for nine probability levels. The actual dates of the last occurrence in spring and the first occurrence in the fall are recorded and the number of days between these dates each year is computed. These periods are defined as the length of the growing season, the freeze-free period, or simply the number of days between the indicated threshold temperatures. The number of days from the first freeze in fall to the last freeze in spring is sometimes referred to as the dormant period.

This period is not the same as the Freeze Index described in the EPA-1 program which is computed by accumulating the daily differences between the mean daily temperature and 32° F. The freeze tables described in the previous paragraph are computed from daily minimum temperatures instead of the mean temperature. Another difference is that the freeze tables make no provision for the effect of warmer days that may follow the first low temperature in the fall, or those that precede the last one in the spring, while the Freeze Index does.

Hourly observations of surface wind direction and speed, including peak gusts, are taken routinely at most airport stations. Daily peak gusts are also reported at many of these stations. A variety of wind summaries covering 5 to 10 years of record are readily available at the NCC and can be furnished for the cost of duplication. Caution should be exercised in using wind summaries, since many of them are prepared for special applications. Some of these include low ceiling-visibility-wind distributions or all weather wind graphs for airport master plans (Figure 19) and extreme wind probabilities for design purposes (Figures 20 and 21). Stations in coastal or mountain regions usually have quite different day and night wind patterns. The wind distribution at the proposed site may be influenced by local conditions and, therefore, quite different from that at the nearest reporting station. Special wind equipment might be installed at the proposed site if conditions warrant; however, analyses of wind direction and speed should be based on at least five or more years of record in order to obtain a representative distribution.

Thom [20] has chosen the annual extreme fastest mile wind speed as the best available measure of wind for design purposes. He found that only airport or open country wind data could be used because of unknown surface friction conditions at city office exposures. Figures (20) and (21) are from Thom's paper and show the 10-year and 25-year mean recurrence intervals in miles per hour. The charts are based on 21 years of record; however, suitable adjustments must be made to the values where experience indicates the wind speeds in the figures are inadequate. These conditions can exist where unusual channeling occurs, such as the Santa Ana in California and the winds along the eastern slopes of the Rockies, especially in the region of Boulder and Colorado Springs.

Thunderstorms and tropical cyclones generally produce their high winds during the summer months, while the highest wind speeds in winter are usually caused by extratropical cyclones. Tropical cyclones are often accompanied by tornadoes and the effects of a well developed tropical storm can extend inland for several hundred miles. Tropical storms that move along the Atlantic coastline in a northeasterly direction can remain intense systems as far north as Maine. According to Thom, thunderstorms account for about one-third of the extreme wind speeds in this country.

Mountain and valley winds move along the axis of a valley [21], blowing uphill (valley wind) by day and downhill (mountain wind) by night. The valley wind sets in about one-half hour after sunrise and continues until about one-half hour before sunset, reaching its greatest strength at the time of maximum insolation along the slopes. On southerly slopes it may reach 14 mph, while on the north facing slopes it is barely noticeable. The mountain wind is due to nocturnal cooling and is somewhat weaker, reaching perhaps 9 mph on occasion, but it is usually stronger a few hundred feet above the ground than at the surface. Detailed information about mixing heights, stability and wind patterns in the upper air are also available [22]. Additional information of interest to planners may be found in the literature [23, 24, 25, 26, 27, 28, 29].

Note: The values in Figures 25-27 are roughly equivalent to the minimum temperatures which have an average return period of 100 years (1%), 33 years (3%) and 20 years (5%).

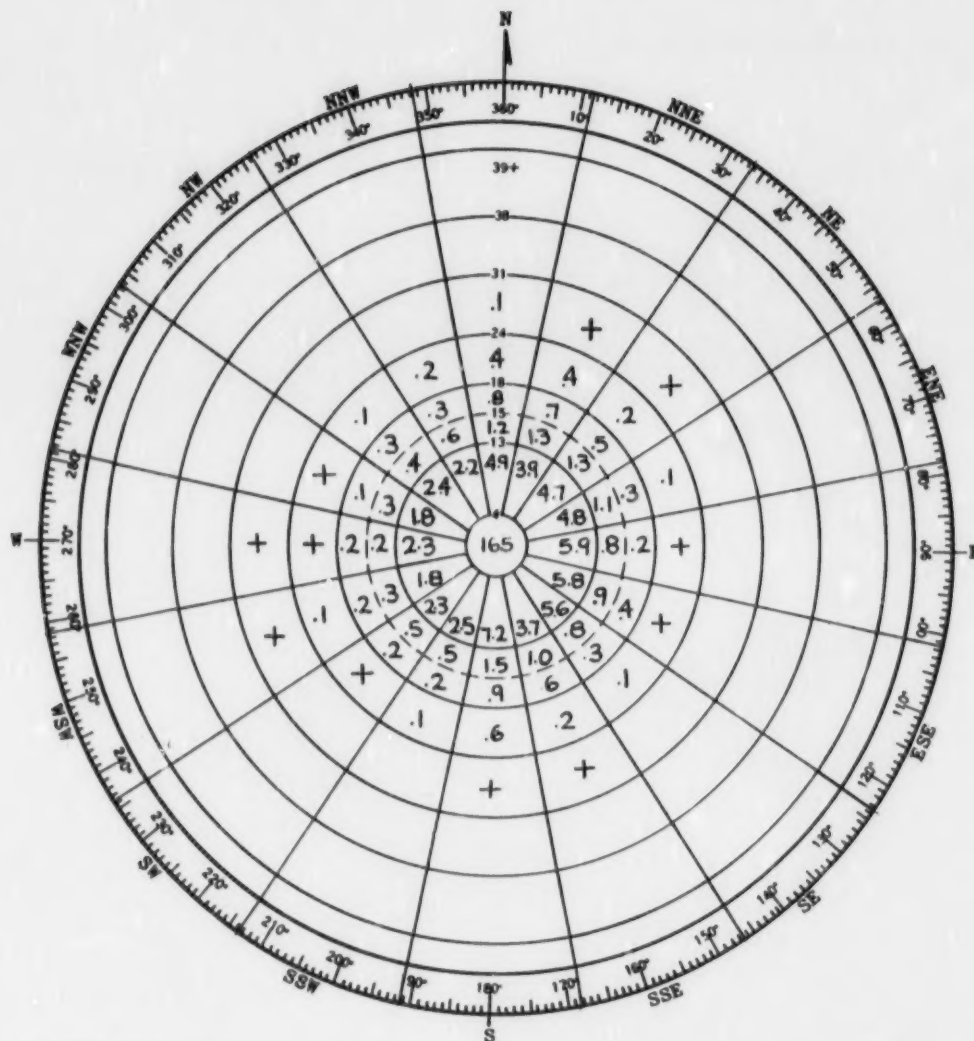
SUPPLEMENTAL INFORMATION

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THE WIND ROSE IS A SCALED GRAPHICAL PRESENTATION OF SURFACE WIND DATA IN TERMS OF SPEED AND DIRECTION. THE RADIAL LINES OF THE DIAGRAM ARE POSITIONED SO THAT AREAS BETWEEN THEM ARE CENTERED ON THE DIRECTION FROM WHICH THE WINDS ARE REPORTED. THE CONCENTRIC CIRCLES REPRESENT LIMITS BETWEEN SPEED GROUPS SECTORS, I.E., 4, 13, 15, 18, 24, 31, 38, AND 39+ MILES PER HOUR. RADII FOR THESE GROUPS ARE ACCURATELY SCALED TO THE RESPECTIVE SPEEDS. THE SEGMENTS ENCLOSED BY RADIAL LINES AND CONCENTRIC CIRCLES ON THE DIAGRAM REPRESENT WIND SPEED-DIRECTION COMBINATIONS. THE DATA FROM A WIND SUMMARY ARE TRANSFERRED TO THE APPROPRIATE AREA ON THE DIAGRAM AS A PERCENTAGE OF THE TOTAL OBSERVATIONS EXAMINED.

16.5 % of the winds were less than 4 m.p.h.

based on 11,576 observations

+ indicates less than 0.05

Fig. 19 Annual distribution of surface wind direction and speed, Boothville, LA, May 1971 — April 1975, 8 observations per day, all weather conditions

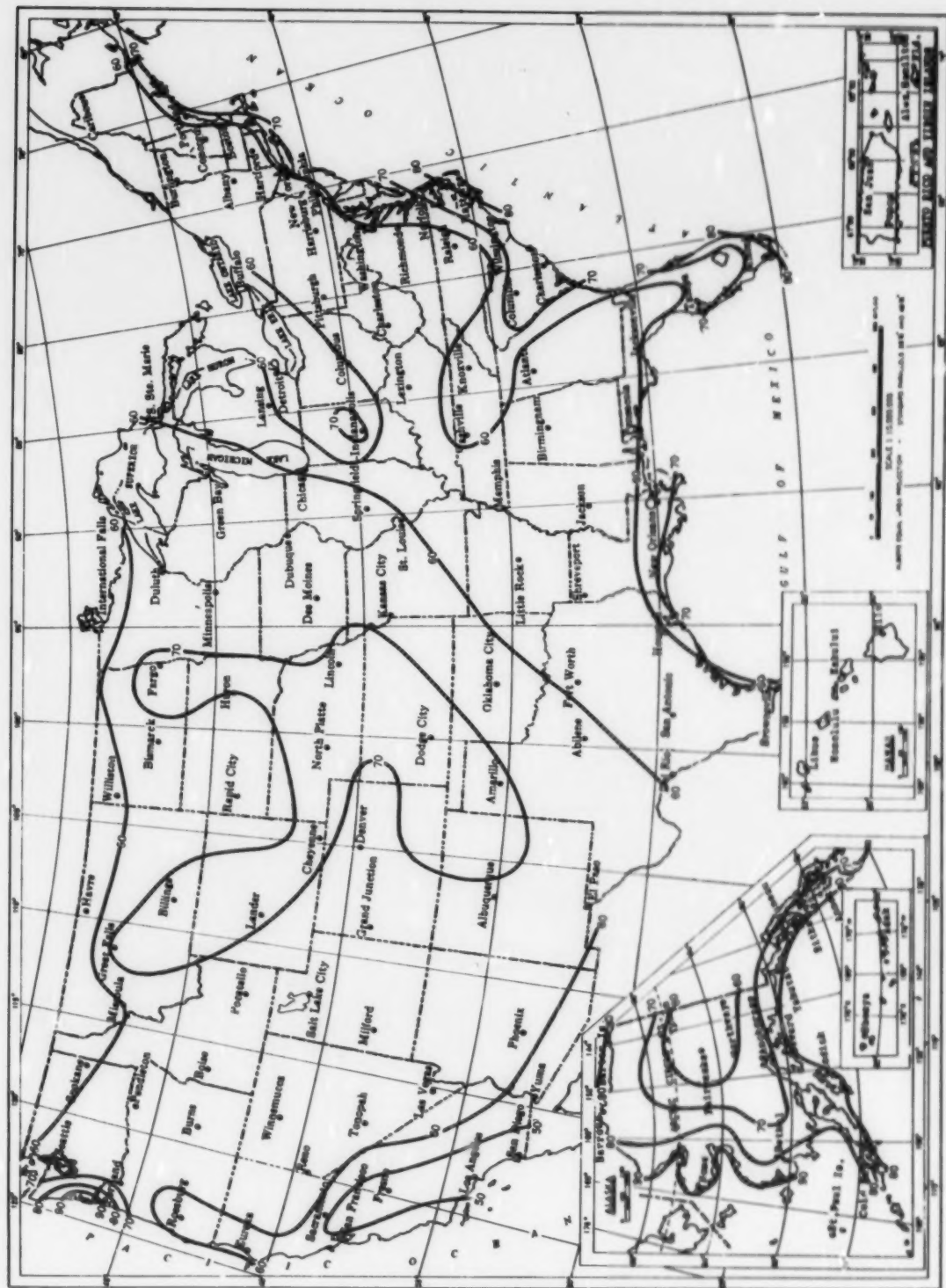


Fig. 21 Isotach 0.10 quantiles, in miles per hour: annual extreme-mile 30 feet above ground, 10-year mean recurrence interval (after Thom)

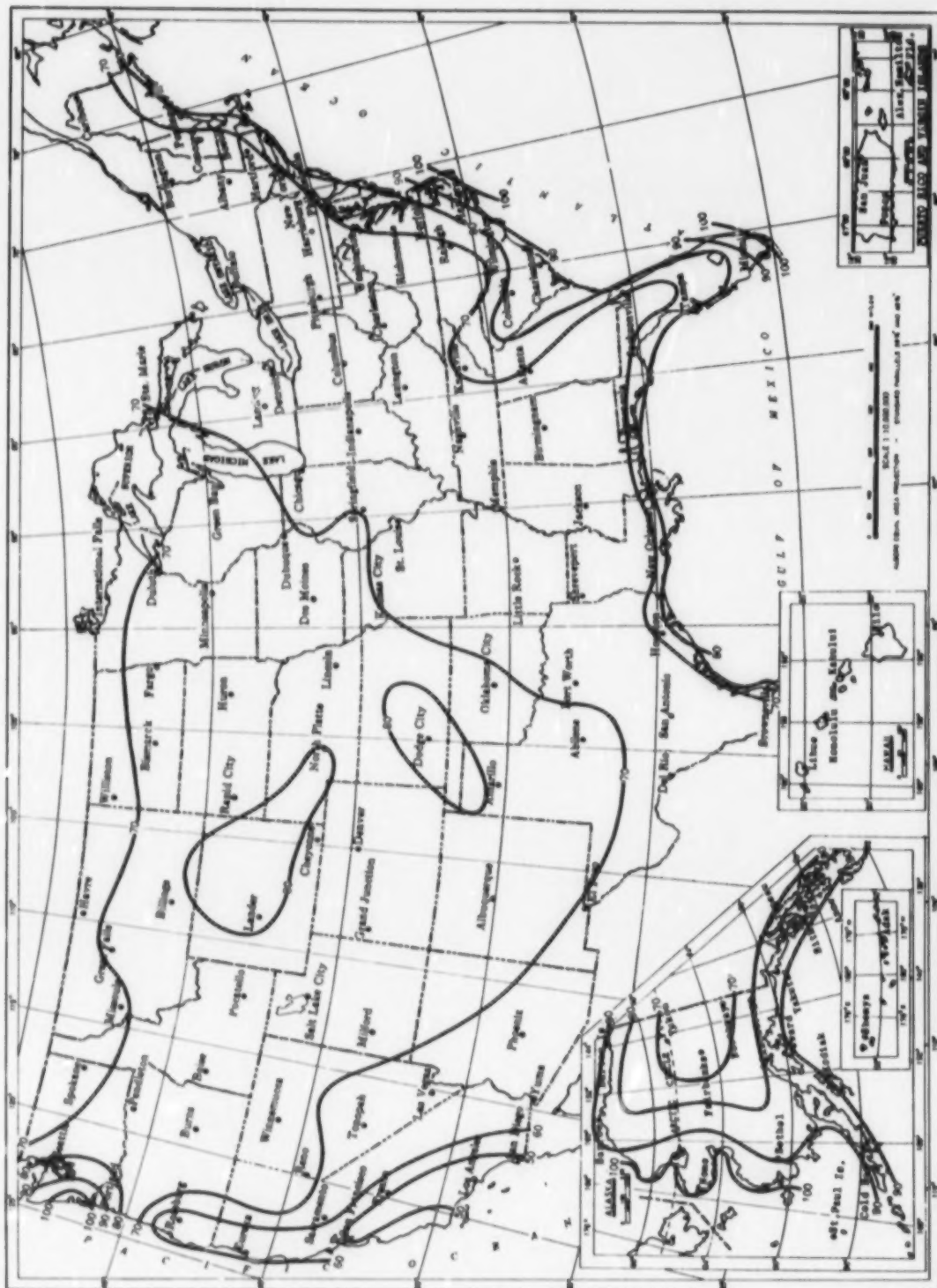


Fig. 22 Isotach 0.04 quantiles, in miles per hour: annual extreme-mile 30 feet above ground, 25-year mean recurrence interval (after Thom)

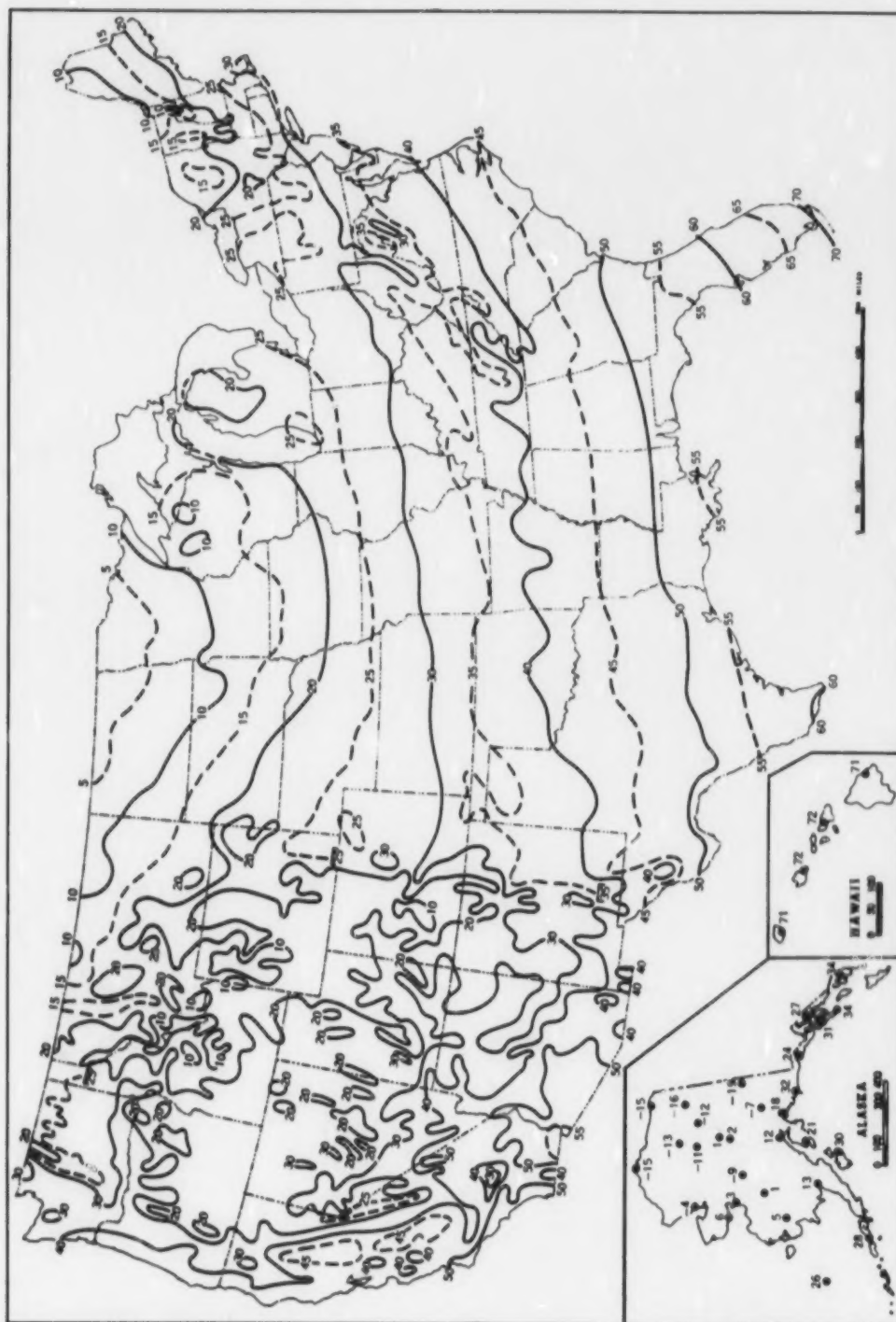


Fig. 23 Normal daily average temperature (°F) for January (1941-70)

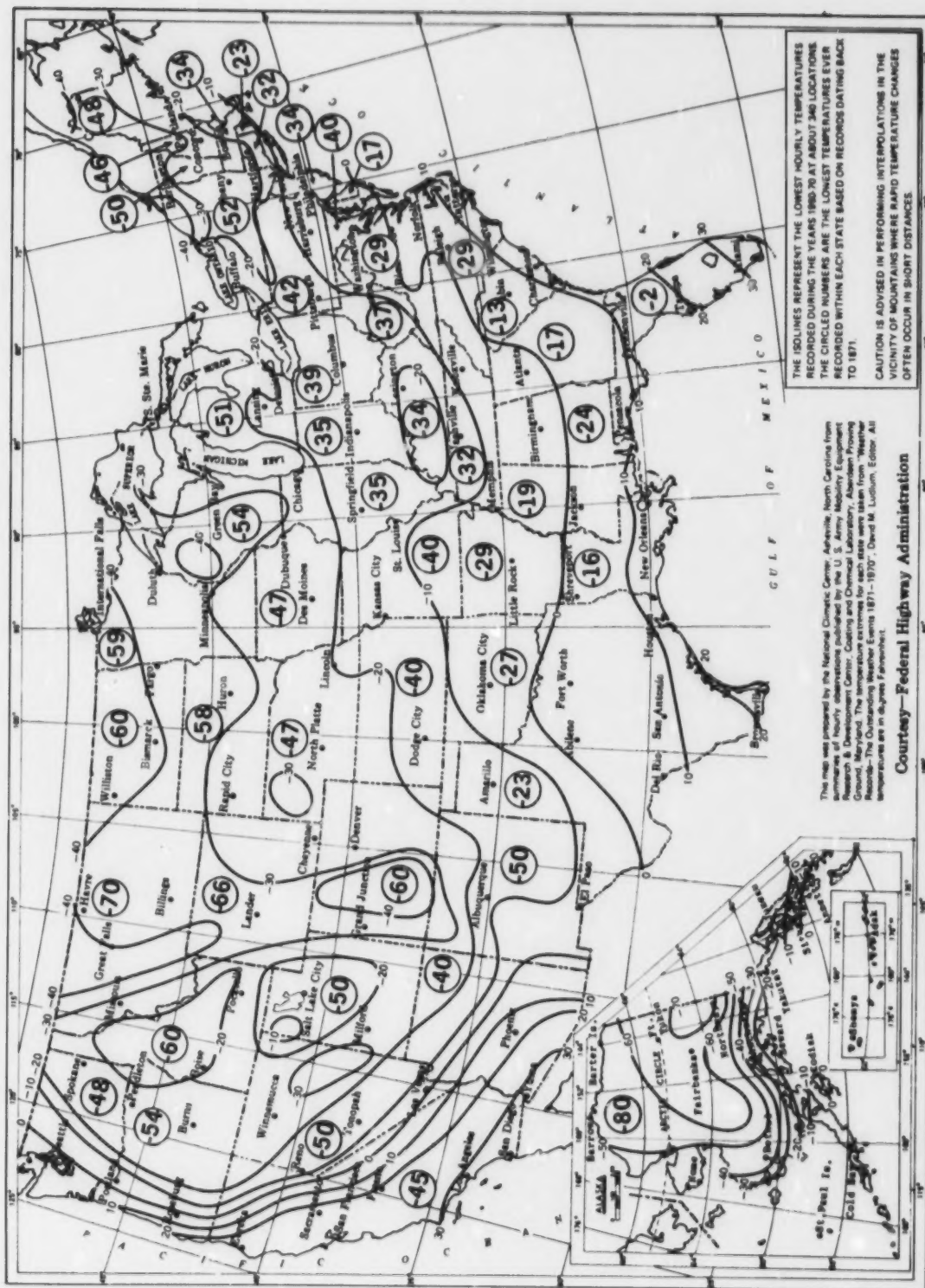


Fig. 24 Extreme low hourly temperatures during the winter season with absolute minimums for each state

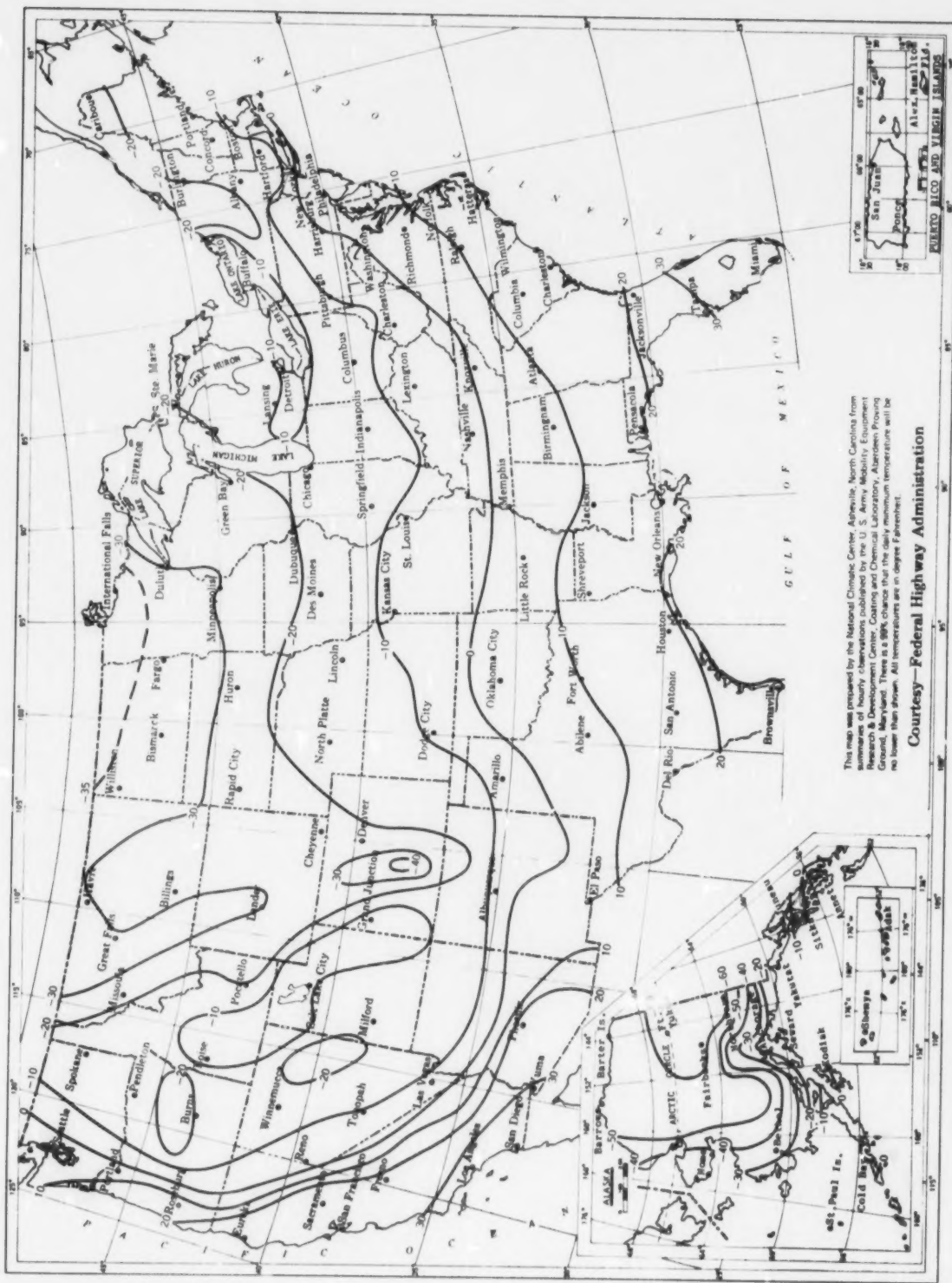


Fig. 25 Minimum temperatures colder than indicated 1% of the hours during the winter season

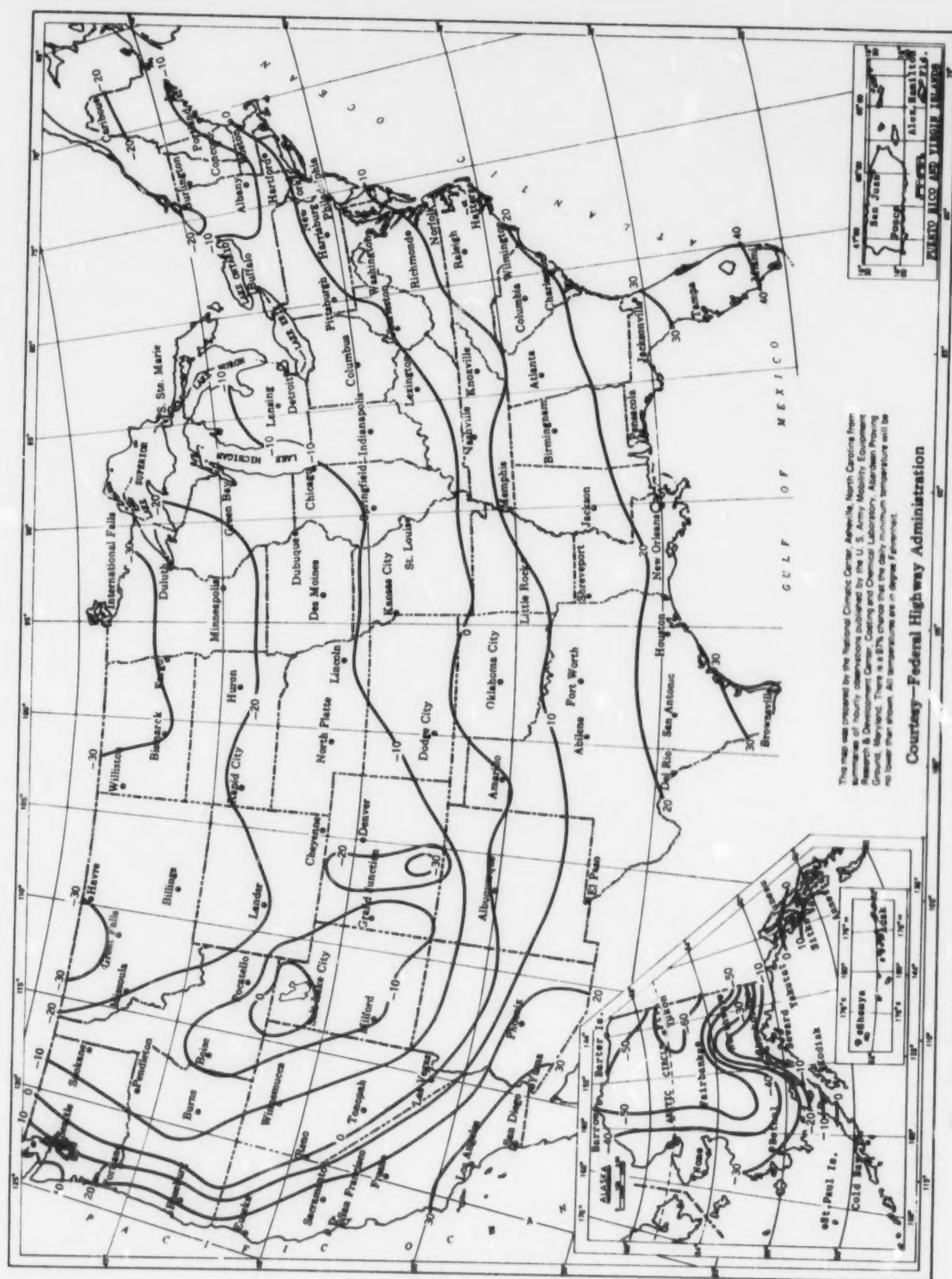


Fig. 26 Minimum temperatures colder than indicated 3% of the hours during the winter season

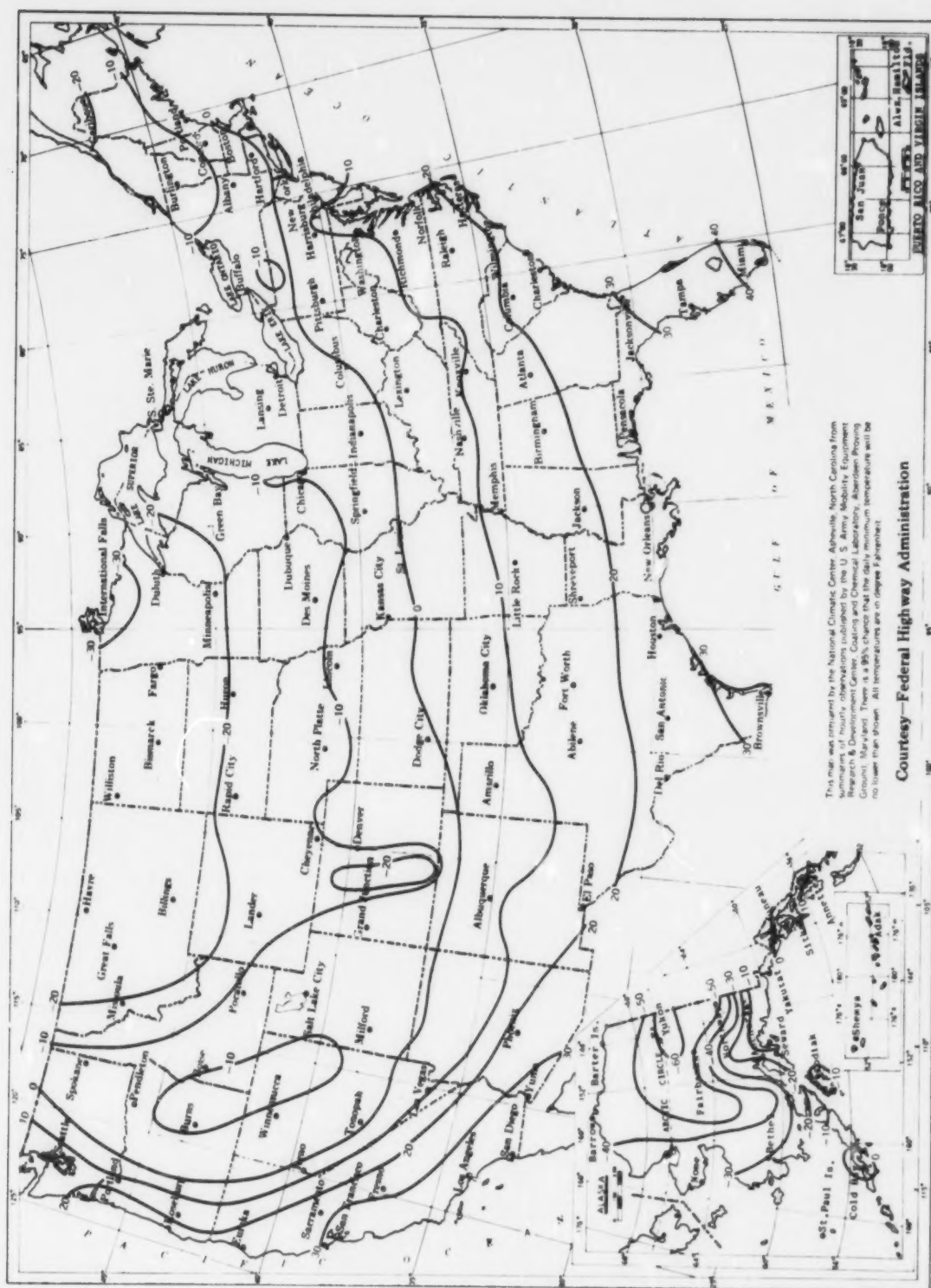


Fig. 27 Minimum temperatures colder than indicated 5% of the hours during the winter season

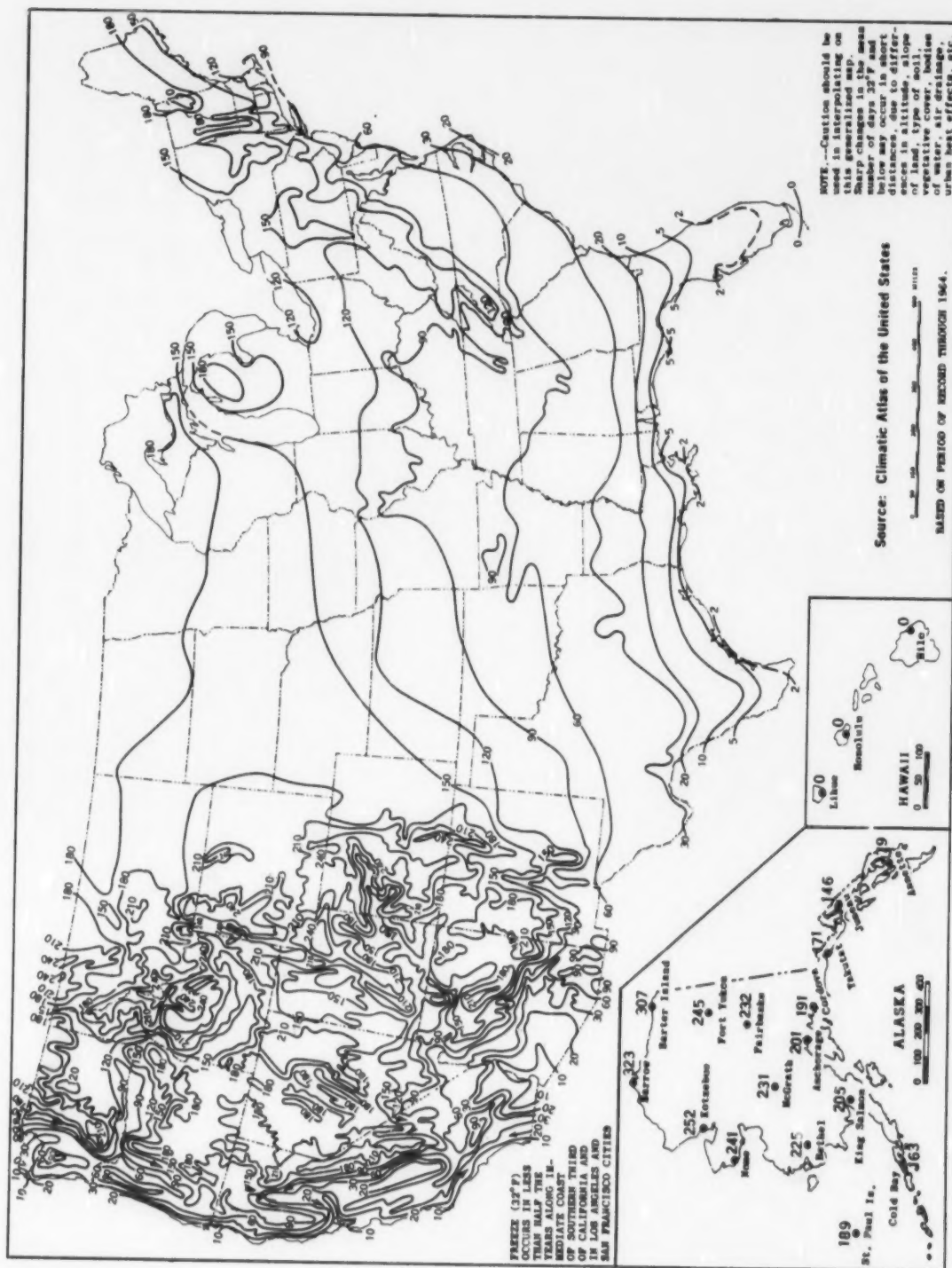
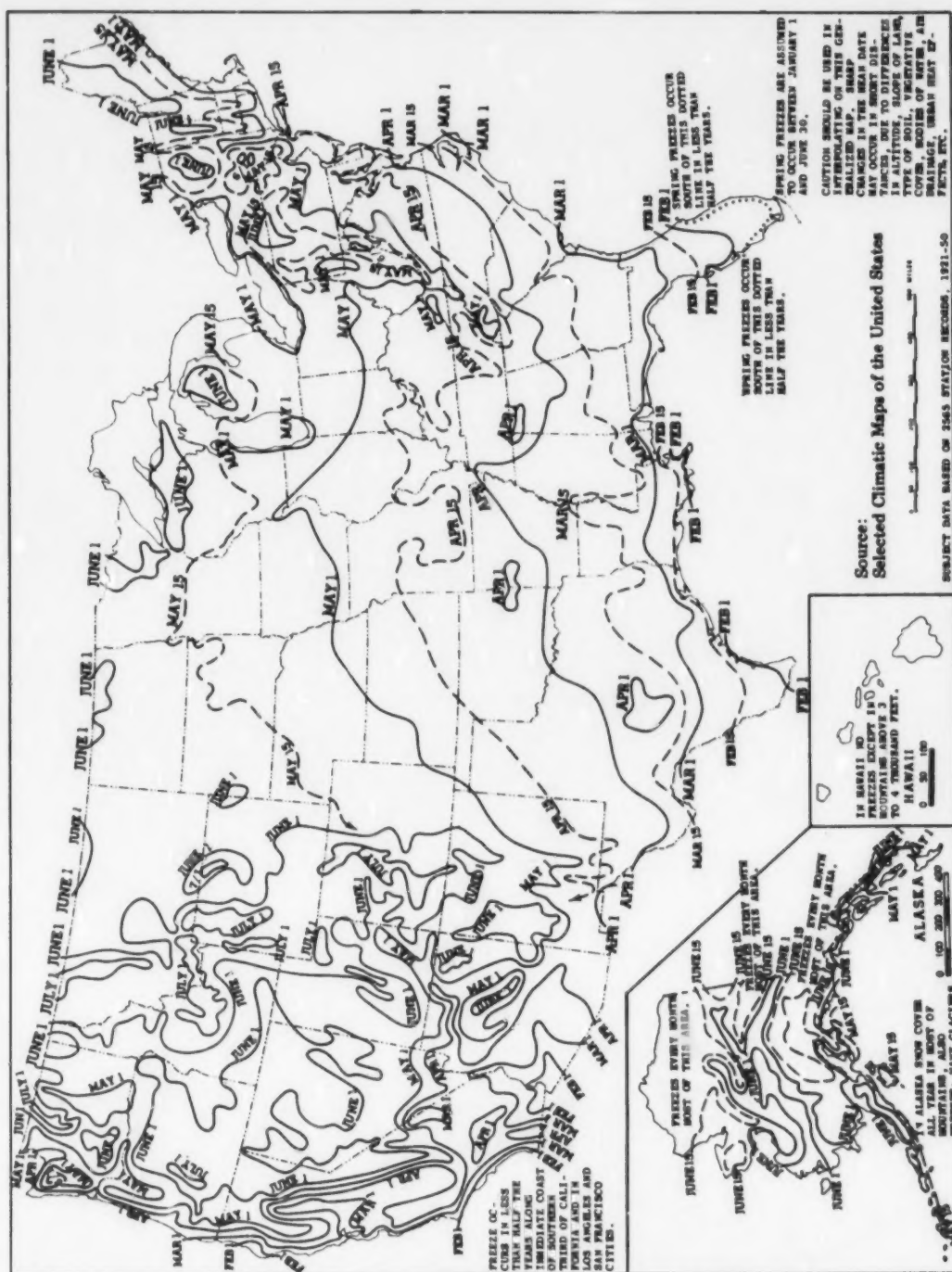


Fig. 29 Mean annual number of days minimum temperature 32°F and below



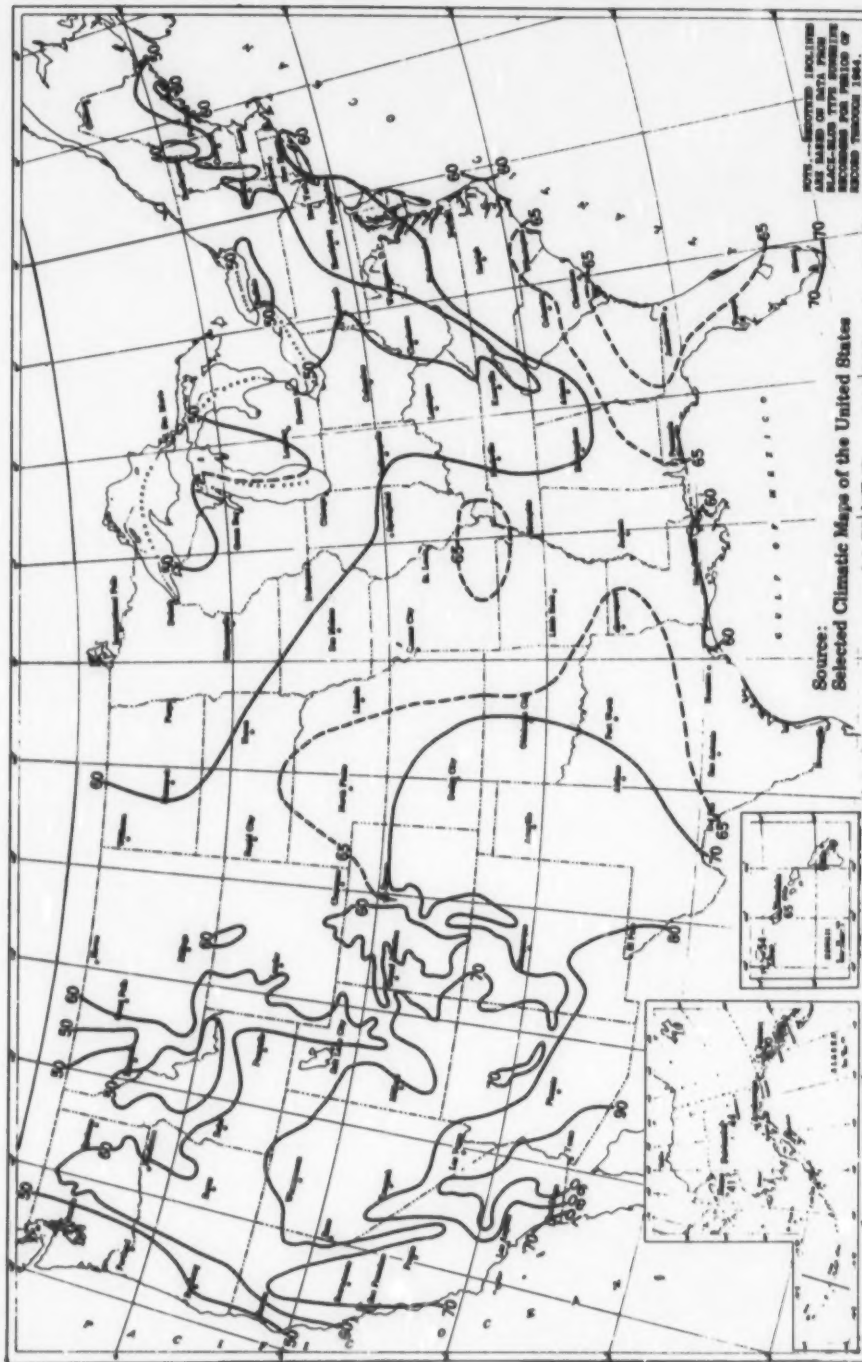


Fig. 33 Mean annual percentage of possible sunshine

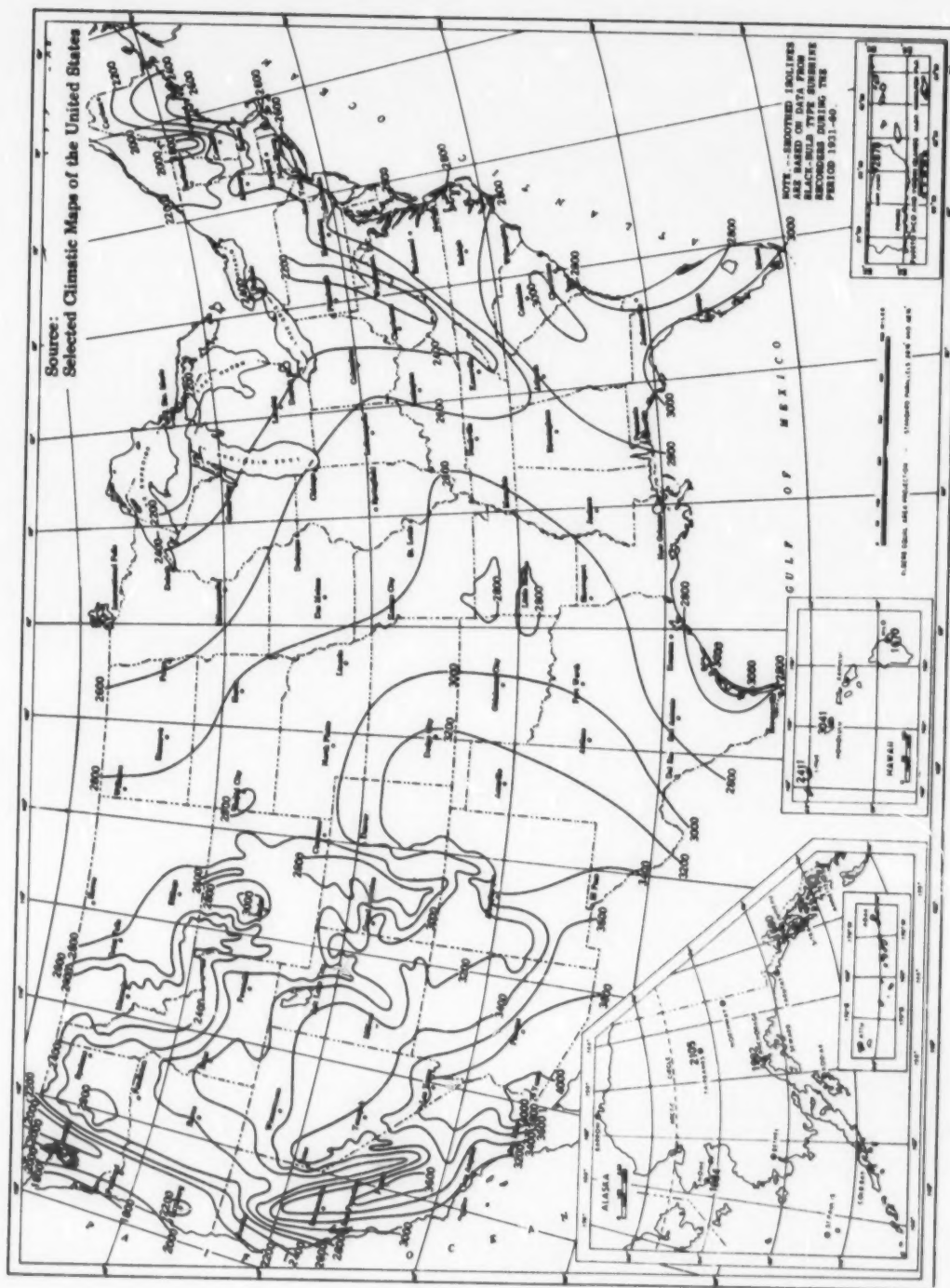


Fig. 34 Mean annual total hours of sunshine

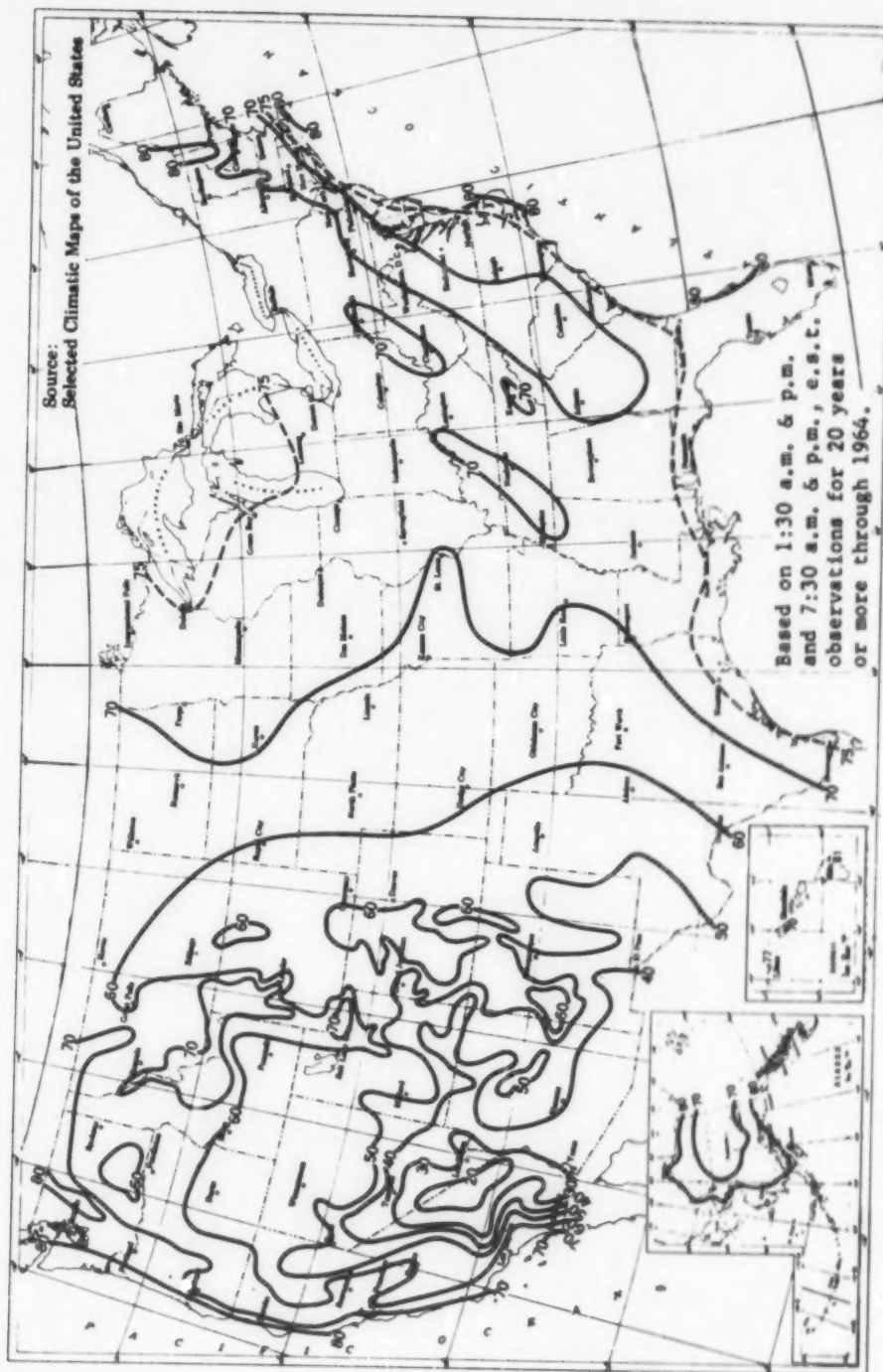


Fig. 35 Mean annual relative humidity (%)

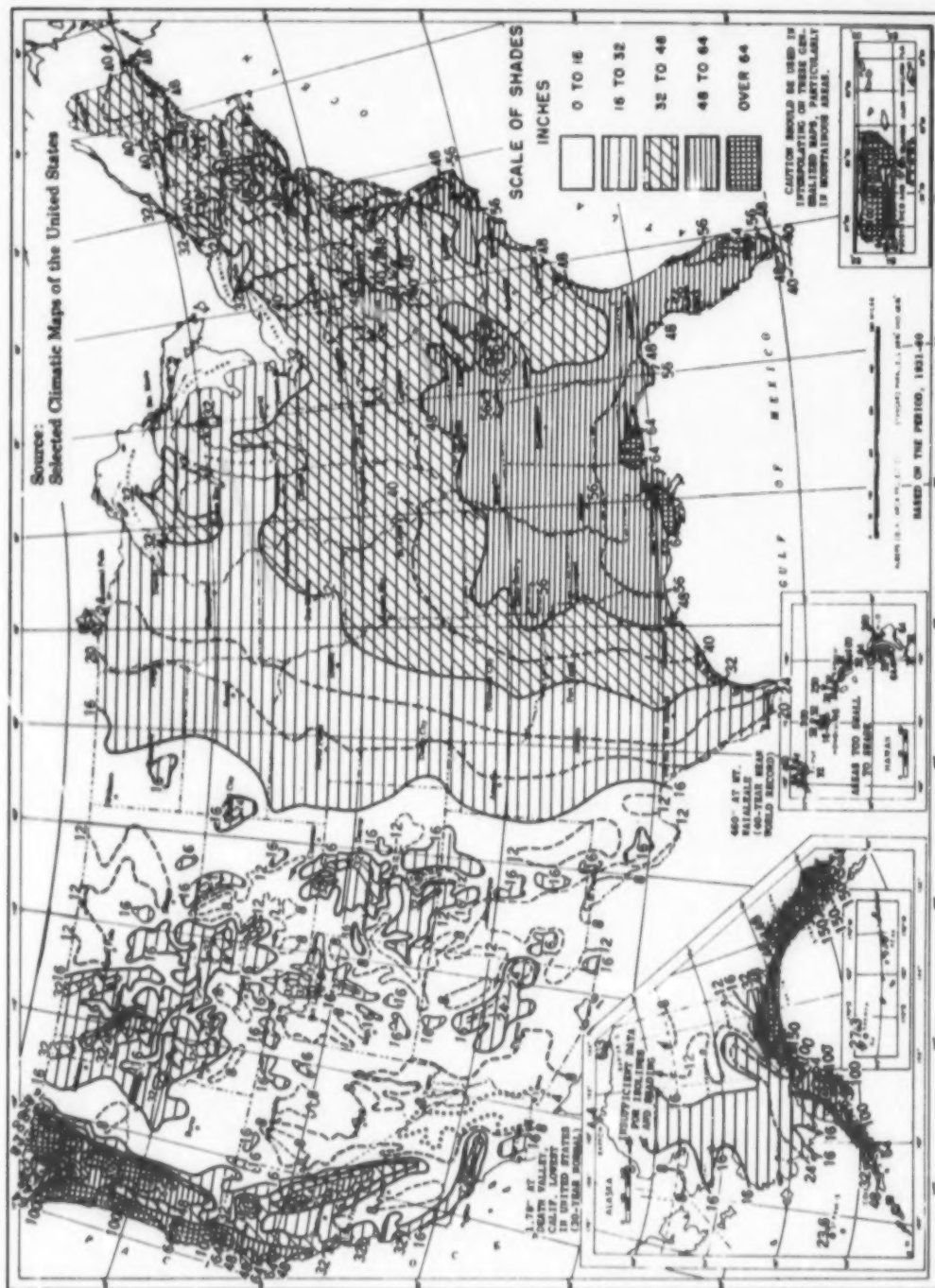


Fig. 36 Normal annual total precipitation (inches)

STATION NAME	.01-.19IN	.20-.49IN	.50-.99IN	>1.00IN	# YEARS
ALABAMA					
ANNISTON	59	25	10	2	16
BIRMINGHAM	74	18	10	3	23
DOTHAN	44	23	10	2	10
GADSDEN	58	28	10	2	16
HUNTSVILLE	74	29	10	3	14
MOBILE	75	27	14	6	14
MONTGOMERY	65	25	9	3	23
MUSCLE SHOALS	60	28	10	2	21
TUSCALOOSA	54	24	10	2	14
ARKANSAS					
EL DORADO	51	23	10	3	23
FAYETTEVILLE	40	27	8	3	4
FORT SMITH	64	20	7	2	24
HARRISON	56	21	7	1	23
HOT SPRINGS	50	24	10	3	17
JONESBORO	48	18	9	3	20
LITTLE ROCK	66	23	10	3	24
TEXARKANA	61	23	10	3	19
FLORIDA					
DAYTONA BEACH	71	25	11	5	25
FT. LAUDERDALE	54	23	13	8	20
FT. MYERS	61	23	14	8	13
GAINESVILLE	53	28	13	5	15
JACKSONVILLE	72	25	12	5	23
MELBOURNE	51	25	11	5	18
MIAMI	75	28	15	6	23
ORLANDO	69	26	13	5	25
PANAMA CITY	44	21	10	5	16
FLORIDA (CONTINUED)					
PENSACOLA	78	25	13	5	5
SARASOTA	43	23	11	5	12
TALLAHASSEE	66	31	16	7	14
TAMPA	62	24	23	5	17
W. PALM BEACH	77	30	15	6	24
GEORGIA					
ALBANY	52	23	8	2	22
ATHENS	72	28	8	2	14
ATLANTA	76	27	9	2	22
AUGUSTA	70	22	8	2	24
COLUMBUS	70	27	10	4	24
MACON	74	24	7	2	24
MOULTREE	53	24	10	4	23
SAVANNAH	72	25	11	4	24
VALDOSTA	70	24	9	8	2
LOUISIANA					
ALEXANDRIA	47	27	12	4	13
BATON ROUGE	63	25	12	5	25
LAPAYETTE	42	26	12	6	20
LAKE CHARLES	56	24	12	5	25
MONROE	48	22	12	3	17
NEW ORLEANS	66	27	15	6	10
SHREVEPORT	66	21	9	3	17
MISSISSIPPI					
LAUREL-HATTIESBURG	52	27	13	5	22
MERIDIAN	59	26	11	3	24
OXFORD	54	28	9	3	21
TUPELO	48	25	10	2	17

Fig. 37 Probable number of days per year that precipitation rates per hour can be expected

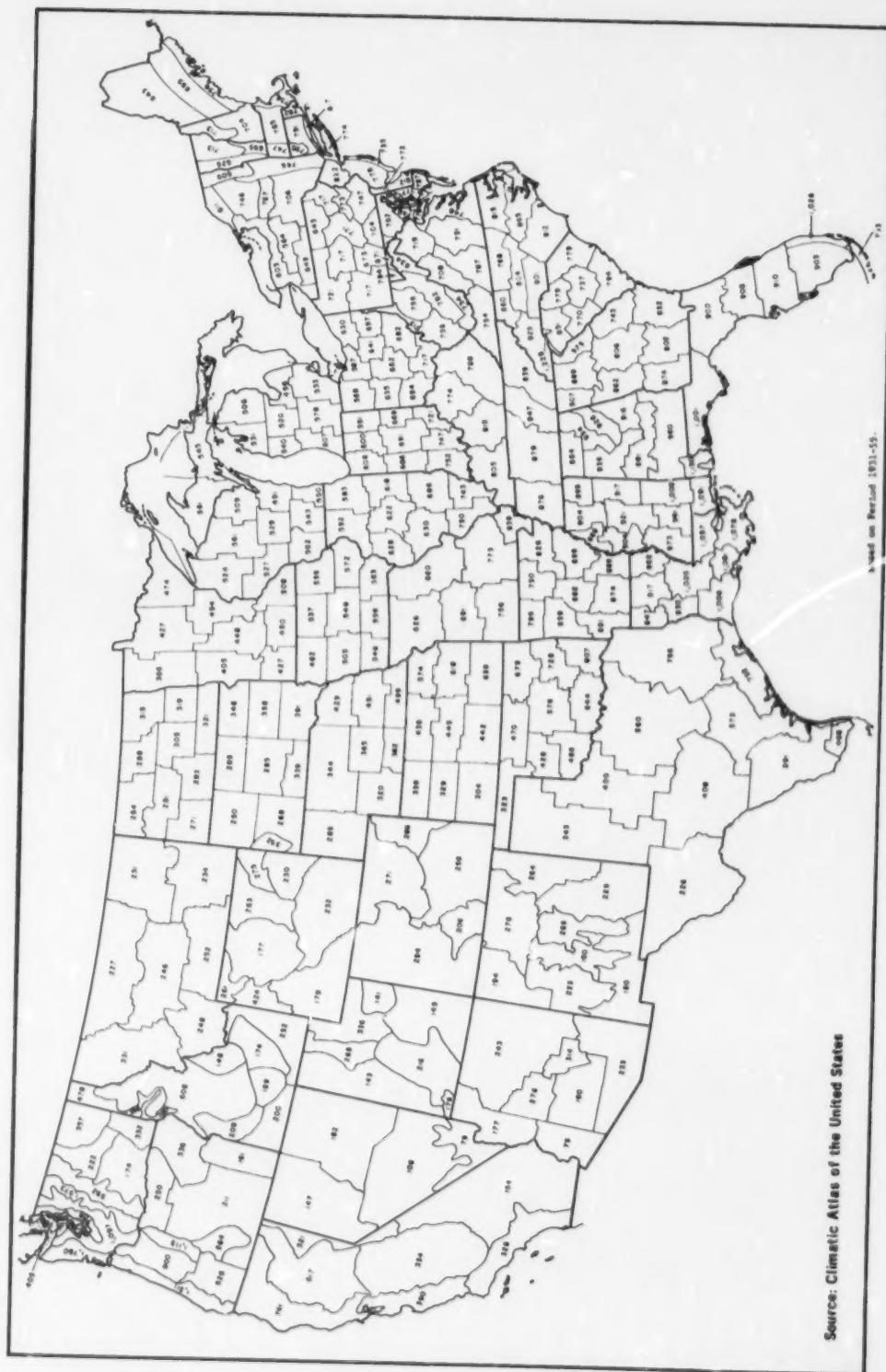


Fig. 38 Mean annual precipitation in millions of gallons of water per square mile, by state climatic divisions

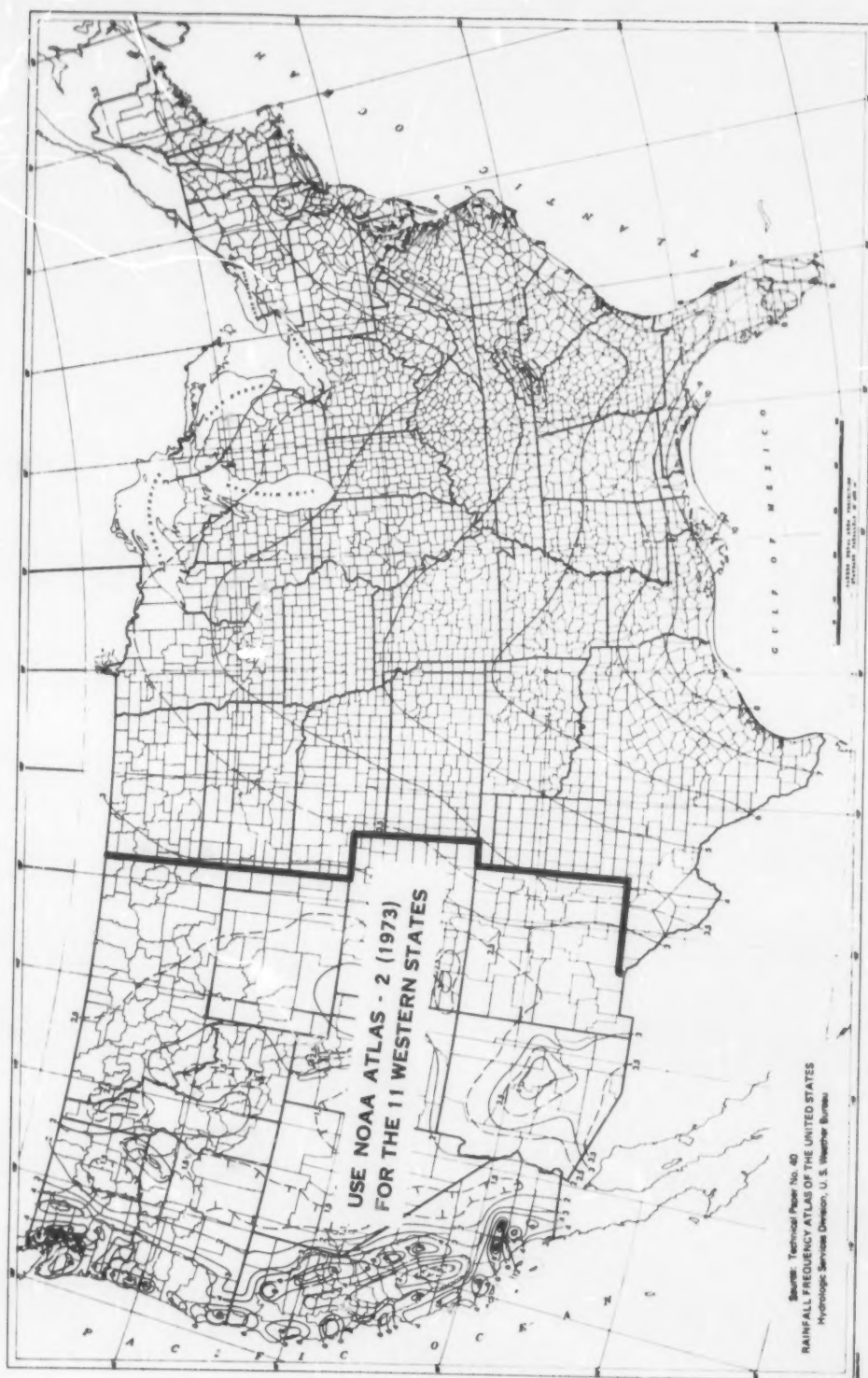


Fig. 39 10-year 24-hour rainfall (inches)



Fig. 40 25-year 24 hour rainfall (inches)

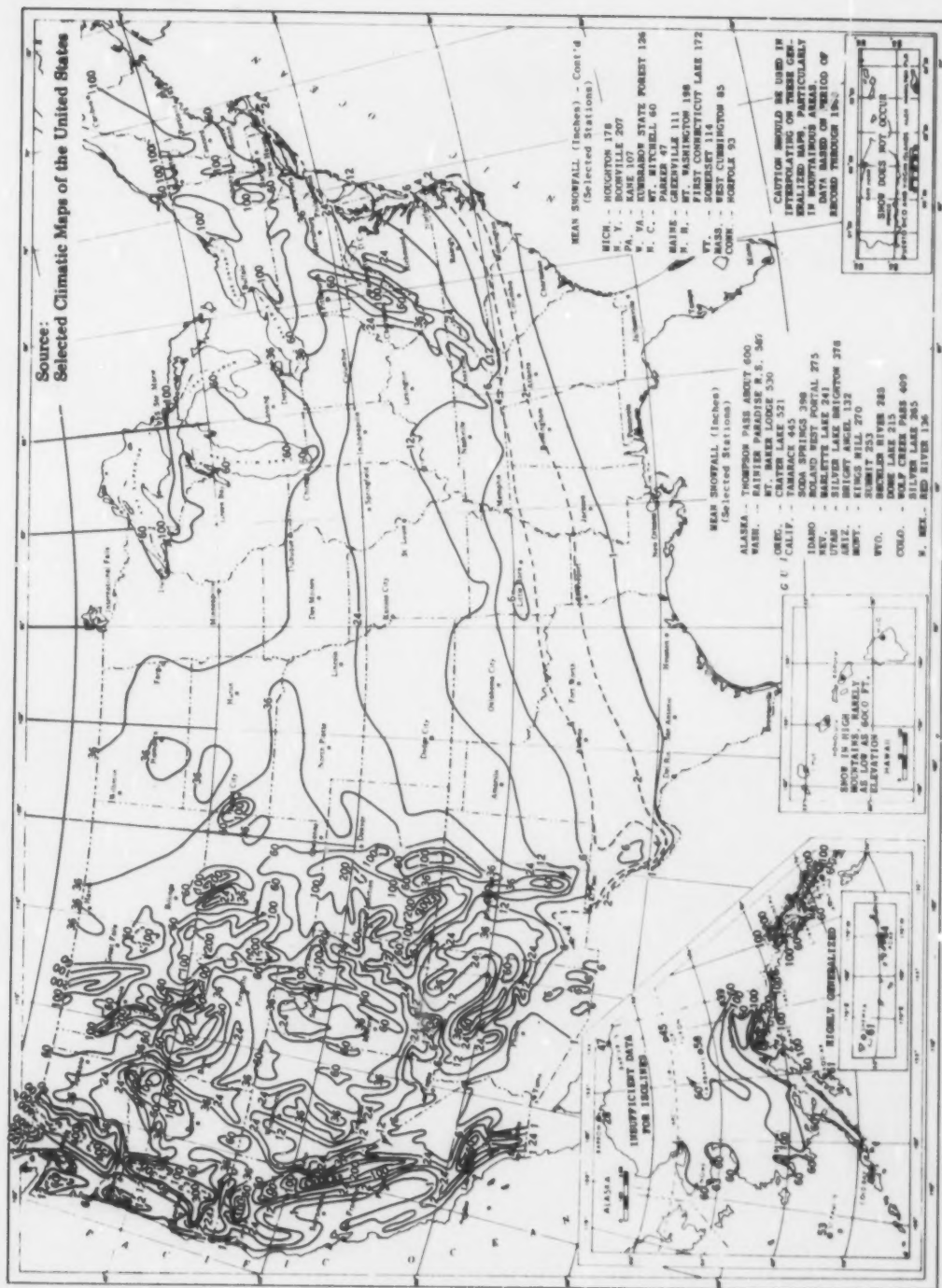
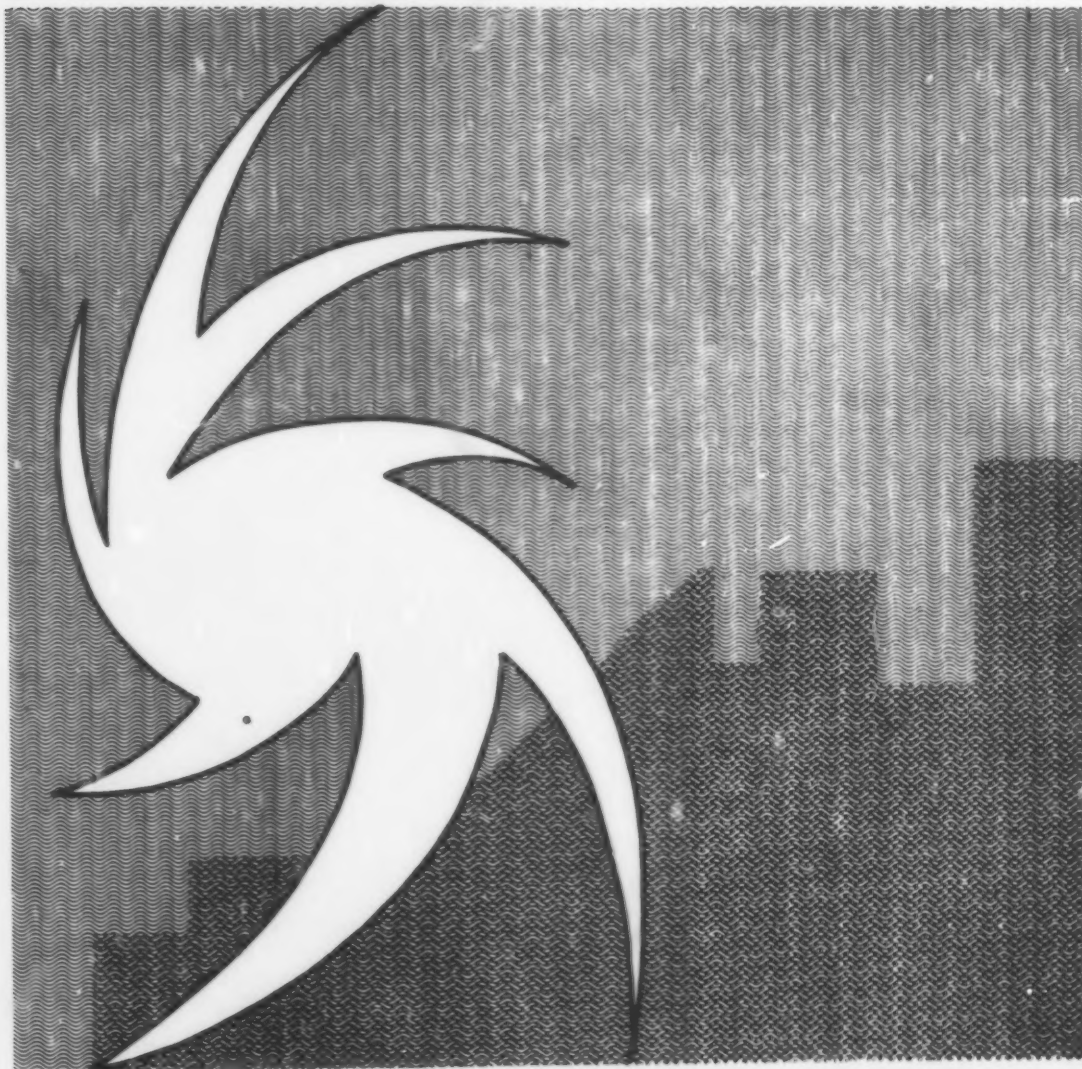


Fig. 41 Mean annual total snowfall (inches)

CLIMATOGRAPHY OF THE UNITED STATES NO. 20

Climate of Greenwood FAA AP, Mississippi



noaa

NATIONAL OCEANIC AND
ATMOSPHERIC ADMINISTRATION

ENVIRONMENTAL
DATA SERVICE

NATIONAL CLIMATIC CENTER
ASHEVILLE, N.C. APRIL 1975

Fig. 42 Climatological summary for Greenwood, MS, from the series, "Climatology of the U. S. No. 20"

LATITUDE N33 30
LONGITUDE W90 12

CLIMATOLOGICAL SUMMARY

GREENWOOD PAA AP, MS
ELEVATION 128

MEANS AND EXTREMES FOR PERIOD 1951-1973

MONTH	TEMPERATURE (°F)												PRECIPITATION TOTALS (INCHES)														
	MEANS			EXTREMES				MEAN NUMBER OF DAYS					MEAN	GREATEST MONTHLY	YEAR	GREATEST DAILY	YEAR	DAY	SNOW SLEET					MEAN NUMBER OF DAYS			
								MARK											MEAN	MAXIMUM MONTHLY	YEAR	GREATEST DEPTH	YEAR	DAY	10 or MORE	50 or MORE	100 or MORE
	80° AND ABOVE	32° AND BELOW	12° AND BELOW	0° AND BELOW	MEAN	MAXIMUM MONTHLY	YEAR	GREATEST DEPTH	YEAR	DAY	10 or MORE	50 or MORE	100 or MORE														
	DAILY MAXIMUM	DAILY MINIMUM	MONTHLY	RECORDED HIGHEST										YEAR	DAY	RECORDED LOWEST	YEAR	DAY	80° AND ABOVE	32° AND BELOW	12° AND BELOW	0° AND BELOW	MEAN	GREATEST MONTHLY	YEAR	GREATEST DAILY	YEAR
JAN	53.3	35.3	44.3	82	72	24	-1	82	12	0	2	14	4.72	12.12	51	3.76	73	21	.9	5.9	60	9.0	62	11	7	3	1
FEB	57.4	37.9	47.6	81.4	67	26	-4	51	3	0	1	9	4.64	10.42	56	3.92	59	12	.6	8.0	60	8.0	51	01	7	3	1
MAR	64.8	44.2	54.5	88.6	65	31	20	60	5	0	0	3	5.83	16.84	73	6.03	55	21	.3	6.0	60	2.0	60	22	8	4	2
APR	75.6	54.0	64.8	92	72	15	32	73	11	0	0	0	5.61	10.91	64	4.64	33	29	.0						7	4	2
MAY	83.5	61.7	72.6	100	51	31	43	54	4	7	0	0	4.30	7.69	67	4.48	62	30	.0						7	3	1
JUN	90.5	69.2	79.8	104.4	54	28	49	56	3	18	0	0	2.86	7.58	61	3.24	66	14	.0						3	2	1
JULY	92.4	71.8	82.1	104.4	54	1	53	67	15	23	0	0	4.65	11.12	63	4.24	59	24	.0						6	3	2
AUG	91.7	70.5	81.1	105	51	30	55	56	23	22	0	0	2.92	7.69	64	3.56	64	16	.0						3	2	1
SEPT	85.9	64.7	75.8	102	54	4	35	67	29	13	0	0	3.00	19.65	58	8.07	58	20	.0						4	2	1
OCT	77.3	52.4	64.9	97.4	54	3	27	52	30	2	0	1	2.56	10.22	70	4.10	70	13	.0						4	2	1
NOV	64.6	42.6	53.6	89	72	1	19	55	29	0	0	6	4.34	13.20	57	3.61	57	13	.0						6	3	1
DEC	56.0	37.5	46.8	81.4	51	6	8	62	13	0	1	11	5.71	11.13	61	6.13	84	28	.3	4.0	63	2.0	63	29	7	4	2
YEAR	74.5	53.5	64.0	105	51	30	-4	51	03	85	4	44	51.14	19.65	58	8.07	58	20	2.1	8.0	60	8.0	51	1	73	33	16

+ ALSO ON EARLIER DATES

FREEZE PROBABILITIES

TEMP	.10	PROBABILITY OF LATER DATE IN SPRING (MO/DA) THAN INDICATED								.90
		.20	.30	.40	.50	.60	.70	.80		
32	3/30	3/25	3/22	3/19	3/17	3/14	3/11	3/8	3/3	
28	3/23	3/18	3/7	3/2	2/25	2/20	2/15	2/8	1/30	
24	3/12	2/28	2/20	2/13	2/6	1/30	1/23	1/15	1/3	
20	2/25	2/16	2/9	2/3	1/28	1/22	1/15	1/6	0/0	
16	2/7	1/24	1/10	12/17	0/0	0/0	0/0	0/0	0/0	
0/0 PROBABILITY OF OCCURRENCE OF THRESHOLD TEMP IS LESS THAN INDICATED PROBABILITY										
TEMP	.10	PROBABILITY OF EARLIER DATE IN FALL (MO/DA) THAN INDICATED								.90
		.20	.30	.40	.50	.60	.70	.80		
32	10/23	10/20	11/1	11/4	11/8	11/11	11/14	11/18	11/23	
28	10/31	11/8	11/13	11/18	11/23	11/27	12/1	12/8	12/15	
24	11/10	11/18	11/24	11/29	12/4	12/8	12/13	12/19	12/27	
20	11/26	12/8	12/14	12/20	1/3	1/12	1/22	2/9	0/0	
16	12/17	1/4	1/23	0/0	0/0	0/0	0/0	0/0	0/0	
0/0 PROBABILITY OF OCCURRENCE OF THRESHOLD TEMP IS LESS THAN INDICATED PROBABILITY										

TEMP	PROBABILITY OF LONGER THAN INDICATED FREEZE FREE PERIOD (DAYS)									.90
	.10	.20	.30	.40	.50	.60	.70	.80		
32	252	240	247	239	235	232	228	224	218	
28	302	291	283	276	270	263	257	249	237	
24	337	324	314	307	300	292	284	276	263	
20	365	355	345	333	327	320	317	307	295	
16	365	355	345	333	327	320	317	307	295	

PRECIPITATION WITH PROBABILITY EQUAL OR LESS THAN

LVL	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
0.05	1.20	1.75	1.93	2.41	1.76	0.28	1.14	0.55	0.18	0.00	0.45	1.00
0.10	1.63	2.19	2.46	2.91	1.45	0.48	1.57	0.91	0.36	0.08	1.24	2.41
0.20	2.31	2.81	3.27	3.62	2.76	0.87	2.24	1.24	0.73	1.03	1.87	3.20
0.30	2.91	3.32	3.95	4.70	2.70	1.27	2.86	1.63	1.14	1.45	2.45	3.68
0.40	3.51	3.81	4.41	4.74	3.21	1.70	3.43	2.03	1.60	1.84	3.04	4.52
0.50	4.13	4.32	5.28	5.29	3.84	2.18	4.08	2.44	2.14	2.25	3.47	5.18
0.60	4.84	4.86	6.04	5.88	4.44	2.76	4.98	2.95	2.79	2.89	4.39	5.92
0.70	5.64	5.49	6.86	6.40	5.11	3.47	5.96	3.53	3.63	3.22	5.23	6.72
0.80	6.68	6.29	7.92	7.42	5.87	4.45	6.62	4.29	4.81	3.84	6.34	7.70
0.90	6.47	7.53	8.75	8.72	7.46	6.10	8.41	5.59	6.80	4.95	8.24	9.56
0.95	9.41	8.65	11.12	9.40	8.42	7.66	9.87	6.69	8.78	5.85	9.83	10.91

MEDIAN PRECIPITATION AMOUNTS (0.50 PROBABILITY LEVEL) IN THIS TABLE DIFFER FROM THE MEANS SHOWN IN THE ABOVE TABLE BECAUSE OF THE METHOD USED IN MAKING THE COMPUTATIONS. THESE VALUES WERE DETERMINED FROM THE INCOMPLETE GAMMA DISTRIBUTION WHOSE CURVE HAS BEEN FOUND TO GIVE BEST FITS TO PRECIPITATION CLIMATOLOGICAL SERIES.

Fig. 42a Climatological summary for Greenwood, MS, from the series, "Climatography of the U.S. No. 20"

STATION: 22 3627													MAX TEMP													
VR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL													
91	56.6	58.1	66.1	72.8	83.4	90.1	93.3	96.7	88.3	78.9	59.8	59.8	78.8	90.1	93.3	96.7	88.3	78.9	59.8	59.8	78.8	90.1	93.3	96.7	88.3	
92	61.6	61.7	63.0	72.2	83.9	97.3	97.3	94.3	87.3	72.0	62.0	59.0	73.9	90.1	93.3	96.7	88.3	78.9	59.8	59.8	78.8	90.1	93.3	96.7	88.3	
93	59.6	59.1	70.2	73.1	83.1	97.3	97.3	92.4	82.7	60.1	50.7	43.3	70.0	90.1	93.3	96.7	88.3	78.9	59.8	59.8	78.8	90.1	93.3	96.7	88.3	
94	57.3	64.8	65.8	80.1	77.0	98.9	97.3	98.0	84.9	53.0	78.7	64.9	77.3	90.1	93.3	96.7	88.3	78.9	59.8	59.8	78.8	90.1	93.3	96.7	88.3	
95	53.0	57.9	69.0	78.0	86.3	97.3	92.3	91.0	81.3	77.0	63.3	59.7	73.4	90.1	93.3	96.7	88.3	78.9	59.8	59.8	78.8	90.1	93.3	96.7	88.3	
96	51.3	61.7	63.7	74.0	86.4	88.6	94.3	93.4	86.0	79.4	63.0	62.0	78.0	90.1	93.3	96.7	88.3	78.9	59.8	59.8	78.8	90.1	93.3	96.7	88.3	
97	53.0	62.0	62.9	77.3	83.8	88.6	91.3	90.3	80.9	69.9	61.9	59.9	73.9	90.1	93.3	96.7	88.3	78.9	59.8	59.8	78.8	90.1	93.3	96.7	88.3	
98	49.6	68.1	57.3	74.0	83.1	88.3	91.4	90.4	83.3	74.9	64.3	59.0	71.0	90.1	93.3	96.7	88.3	78.9	59.8	59.8	78.8	90.1	93.3	96.7	88.3	
99	52.7	58.3	63.9	74.3	83.0	87.3	91.0	91.0	80.4	74.3	61.3	56.0	74.0	90.1	93.3	96.7	88.3	78.9	59.8	59.8	78.8	90.1	93.3	96.7	88.3	
00	50.8	50.2	53.4	78.2	81.0	90.3	94.0	90.9	86.1	77.0	63.3	59.0	73.0	90.1	93.3	96.7	88.3	78.9	59.8	59.8	78.8	90.1	93.3	96.7	88.3	
01	48.9	61.3	69.0	72.3	81.1	89.7	88.9	89.3	83.7	77.0	61.9	54.0	72.9	90.1	93.3	96.7	88.3	78.9	59.8	59.8	78.8	90.1	93.3	96.7	88.3	
02	49.1	63.0	59.4	73.2	84.0	88.6	93.3	94.6	93.7	86.4	78.3	61.7	52.3	74.3	90.1	93.3	96.7	88.3	78.9	59.8	59.8	78.8	90.1	93.3	96.7	88.3
03	47.7	53.0	72.0	77.7	84.9	91.1	90.0	91.4	89.1	84.0	66.0	44.0	74.0	90.1	93.3	96.7	88.3	78.9	59.8	59.8	78.8	90.1	93.3	96.7	88.3	
04	53.7	53.0	66.6	77.0	84.3	91.9	92.0	90.1	86.8	73.3	67.3	57.4	74.3	90.1	93.3	96.7	88.3	78.9	59.8	59.8	78.8	90.1	93.3	96.7	88.3	
05	53.7	56.3	56.2	79.4	86.0	90.0	93.6	91.4	85.7	73.3	63.3	53.3	73.0	90.1	93.3	96.7	88.3	78.9	59.8	59.8	78.8	90.1	93.3	96.7	88.3	
06	46.2	54.2	67.4	75.2	82.1	89.1	95.3	89.7	83.3	73.8	67.3	53.7	73.1	90.1	93.3	96.7	88.3	78.9	59.8	59.8	78.8	90.1	93.3	96.7	88.3	
07	54.4	52.9	71.4	78.0	78.4	88.6	86.9	84.3	80.1	76.8	64.4	58.0	72.0	90.1	93.3	96.7	88.3	78.9	59.8	59.8	78.8	90.1	93.3	96.7	88.3	
08	50.1H	49.9	63.4	73.6	79.3	88.7	88.3	88.7	82.7	76.4	62.0	52.3	71.0H	90.1	93.3	96.7	88.3	78.9	59.8	59.8	78.8	90.1	93.3	96.7	88.3	
09	54.0	53.4	57.9	73.0	84.0	90.9	93.7	90.9	86.1	76.9	64.9	54.9	74.0	90.1	93.3	96.7	88.3	78.9	59.8	59.8	78.8	90.1	93.3	96.7	88.3	
70	49.3	55.9	62.7	77.3	86.3	90.8	91.3	91.1	81.7	76.9	63.0	61.9	73.1	90.1	93.3	96.7	88.3	78.9	59.8	59.8	78.8	90.1	93.3	96.7	88.3	
71	56.7	60.0	63.3	76.3	81.3	92.6	91.4	91.3	88.7	83.8	68.7	63.1	76.6	90.1	93.3	96.7	88.3	78.9	59.8	59.8	78.8	90.1	93.3	96.7	88.3	
72	60.0	61.0	69.3	78.1	83.0	90.9	90.9	93.3	91.2	78.0	61.2	58.3	76.6	90.1	93.3	96.7	88.3	78.9	59.8	59.8	78.8	90.1	93.3	96.7	88.3	
73	53.5	56.9	71.8	70.3H	79.2	91.0	90.0	88.9	87.2	80.9	70.1	53.2	74.7H	90.1	93.3	96.7	88.3	78.9	59.8	59.8	78.8	90.1	93.3	96.7	88.3	
SUM	1226.2	1319.1	1491.3	1738.0	1919.9	2080.9	2125.9	2108.4	1998.4	1778.3	1483.1	1287.6	1713.4													
STATION: 22 3627													MIN TEMP													
VR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL													
91	37.0	38.0	47.4	51.1	59.2	70.2	73.2	72.8	64.8	52.9	38.1	41.1	53.9	64.8	73.2	73.2	72.8	64.8	52.9	38.1	41.1	53.9	64.8	73.2	73.2	
92	44.4	43.8	43.9	49.4	60.3	72.1	71.9	71.8	60.4	38.0	20.7	38.3	53.9	64.8	73.2	73.2	72.8	64.8	52.9	38.1	41.1	53.9	64.8	73.2	73.2	
93	39.0	38.3	48.9	49.1	54.3	73.8	73.7	68.2	60.4	30.3	27.6	33.9	53.9	64.8	73.2	73.2	72.8	64.8	52.9	38.1	41.1	53.9	64.8	73.2	73.2	
94	38.4	41.3	43.6	47.1	57.6	69.0	73.4	73.1	64.4	34.1	39.9	33.2	54.0	64.8	73.2	73.2	72.8	64.8	52.9	38.1	41.1	53.9	64.8	73.2	73.2	
95	34.9	38.4	46.4	57.2	64.0	64.4	72.7	70.8	63.6	48.8	40.0	37.1	53.9	64.8	73.2	73.2	72.8	64.8	52.9	38.1	41.1	53.9	64.8	73.2	73.2	
96	32.2	42.9	43.0	52.0	63.0	68.1	71.3	69.9	59.8	34.0	40.4	44.1	53.9	64.8	73.2	73.2	72.8	64.8	52.9	38.1	41.1	53.9	64.8	73.2	73.2	
97	37.3	48.3	43.2	53.0	63.0	70.9	71.8	69.3	58.2	31.2	48.9	40.2H	53.9	64.8	73.2	73.2	72.8	64.8	52.9	38.1	41.1	53.9	64.8	73.2	73.2	
98	31.0	30.3	41.3	53.2	63.2	69.9	72.7	70.3	67.0	22.3	44.3	32.8	53.9	64.8	73.2	73.2	72.8	64.8	52.9	38.1	41.1	53.9	64.8	73.2	73.2	
99	32.3	39.0	42.0	52.1	63.9	68.9	71.3	72.3	60.2	27.2	38.1	36.0	53.9	64.8	73.2	73.2	72.8	64.8	52.9	38.1	41.1	53.9	64.8	73.2	73.2	
00	38.1	33.9	36.8	54.8	59.9	69.0	72.1	72.2	60.3	33.0	41.3	33.2	53.9	64.8	73.2	73.2	72.8	64.8	52.9	38.1	41.1	53.9	64.8	73.2	73.2	
01	29.6	41.1	49.9	49.6	58.9	66.3	70.2	69.1	64.7	30.0	44.9	37.9	53.9	64.8	73.2	73.2	72.8	64.8	52.9	38.1	41.1	53.9	64.8	73.2	73.2	
02	30.8	44.3	41.3	51.4	64.9	69.3	73.2	71.9	69.9	27.2	44.2	34.0	53.9	64.8	73.2	73.2	72.8	64.8	52.9	38.1	41.1	53.9	64.8	73.2	73.2	
03	28.3	30.3	47.0	57.3	62.7	70.2	71.2	71.8	63.7	24.3	44.3	27.0	53.9	64.8	73.2	73.2	72.8	64.8	52.9	38.1	41.1	53.9	64.8	73.2	73.2	
04	33.7	33.6	43.2	57.4	63.4	70.3	71.3	71.2	64.9	48.9	46.3	39.4	53.9	64.8	73.2	73.2	72.8	64.8	52.9	38.1	41.1	53.9	64.8	73.2	73.2	
05	36.8	36.6	39.9	57.9	63.1	69.1	73.4	71.3	67.0	31.1	48.8	38.4	53.9	64.8	73.2	73.2	72.8	64.8	52.9	38.1	41.1	53.9	64.8	73.2	73.2	
06	31.7	38.0	44.3	54.3	60.8	67.1	73.7	69.1	63.7	48.4	46.1	37.7	53.9	64.8	73.2	73.2	72.8	64.8	52.9	38.1	41.1	53.9	64.8	73.2	73.2	
07	37.1	36.0	47.6	58.1	59.6	68.9	69.1	67.2	59.7	40.4	39.2	40.4	53.9	64.8	73.2	73.2	72.8	64.8	52.9	38.1	41.1	53.9	64.8	73.2	73.2	
08	33.5H	31.0	43.6	58.7	61.7	68.9	69.7	70.3	61.4	33.3	44.1	36.0	53.9	64.8	73.2	73.2	72.8	64.8	52.9	38.1	41.1	53.9	64.8	73.2	73.2	
09	38.0	38.0	39.4	58.8	61.1	68.8	73.3	69.4	63.1	40.0	39.7	33.7	53.9	64.8	73.2	73.2	72.8	64.8	52.9	38.1	41.1	53.9	64.8	73.2	73.2	
70	32.0	36.9	43.4	58.0	61.3	68.6	70.3	71.8	67.8	31.6	41.2	40.0	53.9	64.8	73.2	73.2	72.8	64.8	52.9	38.1	41.1	53.9	64.8	73.2	73.2	
71	37.2	37.2	41.8	51.2	59.1	70.4	71.7	71.1	68.9	38.3	42.6	46.1	54.7	64.8	73.2	73.2	72.8	64.8	52.9	38.1	41.1	53.9	64.8	73.2	73.2	
72	40.4	39.4	43.7	54.3	60.9	67.4	70.0	69.9	69.3	38.8	42.4	38.8	53.9	64.8	73.2	73.2	72.8	64.8	52.9	38.1	41.1	53.9	64.8	73.2	73.2	
73	39.1	34.1	50.0	49.3H	57.3	67.6	71.6	66.7	66.8	36.3	46.9	39.3	53.9	64.8	73.2	73.2	72.8	64.8	52.9	38.1	41.1	53.9	64.8	73.2	73.2	
SUM	812.3	869.4	1016.0	1242.1	1418.4	1590.6	1630.9	1621.0	1487.6	1204.3	980.0	862.2	1229.6													
STATION: 22 3627													AVERAGE TEMPERATURE													
VR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL													
91	46.8	48.4</																								

STATION: 22 3627					TOTAL PRECIPITATION											
YR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL			
51	12.12	3.60	8.28	4.27	.82	0.68	4.71	1.39	2.94	2.91	2.61	10.24	61.63			
52	3.80	3.00	5.12	3.61	4.93	.04	1.34	4.18	1.08	T	3.80	4.51	39.39			
53	4.01	7.70	6.18	9.33	3.95	.22	3.78	.79	1.10	.69	1.05	8.68	48.69			
54	6.14	2.98	2.04	5.68	7.31	.56	2.09	1.19	.82	2.39	3.70	7.44	42.34			
55	4.18	4.95	8.37	7.09	3.46	2.83	4.28	.89	.34	1.29	1.76	3.12	42.70			
56	2.93	10.42	4.60	6.39	2.64	1.54	3.67	.70	.16	3.90	4.43	6.73	47.72			
57	8.43	3.76	3.82	3.69	3.47	4.94	2.99	2.74	3.48	5.07	13.20	2.49	62.04			
58	2.84	3.16	4.85	7.90	7.12	4.13	9.31	3.95	19.63	.91	1.76	.97	60.13			
59	1.71	6.47	3.41	3.51	8.09	2.73	8.16	4.53	1.29	.70	2.91	5.30	30.33			
60	6.60	3.32	3.61	2.48	3.06	1.68	1.74	7.80	3.11	1.30	4.27	5.38	46.33			
61	1.28	8.56	10.10	3.49	1.13	7.58	7.34	2.23	1.20	1.16	11.69	11.13	66.91			
62	3.88	4.83	3.32	4.86	3.45	4.69	1.22	1.34	4.91	4.82	4.77	2.67	48.78			
63	2.26	2.06	6.99	2.53	1.45	2.28	11.12	1.43	.46	.00	3.12	3.70	37.78			
64	3.49	3.33	6.71	10.91	3.93	1.16	3.02	7.69	3.39	2.02	4.73	3.91	39.73			
65	1.78	6.30	6.99	2.13	1.76	.88	2.02	2.78	2.92	1.64	1.04	1.91	32.31			
66	3.17	7.95	1.08	4.33	2.85	4.84	1.86	4.77	1.83	1.30	3.24	62.19	42.19			
67	1.32	4.90	2.34	4.00	7.89	2.89	2.20	3.38	.80	2.00	2.78	10.73	49.53			
68	8.06	2.30	4.69	8.25	6.58	2.12	4.11	4.04	3.78	2.66	7.92	5.40	62.07			
69	4.23	3.13	4.62	3.48	2.73	1.38	4.00	4.52	3.38	2.44	2.83	9.77	40.31			
70	1.67	3.34	6.74	8.28	2.24	3.18	4.59	3.42	1.33	10.22	3.59	4.71	39.29			
71	3.25	4.66	3.29	6.37	3.26	3.38	7.08	4.91	1.20	1.46	1.30	3.96	32.08			
72	8.23	1.21	6.00	4.98	4.62	3.25	4.80	3.86	3.22	3.38	8.40	3.63	37.70			
73	9.23	3.80	10.84	6.46	7.05	.83	10.93	.30	.44	4.13	6.99	6.83	74.07			
SUM	108.47	108.81	134.08	129.04	98.98	65.71	106.93	67.19	69.09	38.81	99.77	131.43	1176.29			

STATION: 22 3627						TOTAL SNOWFALL												
SEASON	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	SEASON					
50-51							2.7	3.0	T	.0								
51-52	.0	.0	.0	.0	T	T	.0	.3	T	.0	.0	.0	.3					
52-53	.0	.0	.0	.0	.0	.0	T	.0	T	.0	T	.0	.0					
53-54	.0	.0	.0	.0	.0	T	T	.0	.0	.0	.0	.0	.0					
54-55	.0	.0	.0	.0	.0	.0	T	.0	.0	.0	.0	.0	.0					
55-56	.0	.0	.0	.0	.0	.0	T	.0	.0	.0	.0	.0	.0					
56-57	.0	.0	.0	.0	.0	.0	.0	.0	T	.0	.0	.0	.0					
57-58	.0	.0	.0	.0	.0	.0	.0	1.0	T	.0	.0	.0	1.0					
58-59	.0	.0	.0	.0	.0	2.0	T	T	.0	.0	.0	.0	2.0					
59-60	.0	.0	.0	.0	.0	.0	T	.0	8.0	T	.0	.0	8.0					
60-61	.0	.0	.0	.0	.0	T	T	T	.0	.0	.0	.0	.0					
61-62	.0	.0	.0	.0	.0	.0	3.0	T	.0	.0	.0	.0	3.0					
62-63	.0	.0	.0	.0	.0	T	T	T	.0	.0	.0	.0	.0					
63-64	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0					
64-65	.0	.0	.0	.0	.0	4.0	T	.0	T	.0	.0	.0	4.3					
65-66	.0	.0	.0	.0	.0	.0	T	.8	T	.0	.0	.0	.8					
66-67	.0	.0	.0	.0	.0	.0	3.0	T	.0	.0	.0	.0	3.0					
67-68	.0	.0	.0	.0	T	T	.4	T	.0	.0	.0	.0	.4					
68-69	.0	.0	.0	.0	.0	1.0	1.0	.3	6.0	.0	.0	.0	8.3					
69-70	.0	.0	.0	.0	.0	T	.0	.1	T	.0	.0	.0	.1					
70-71	.0	.0	.0	.0	.0	.0	T	T	.0	.0	.0	.0	.0					
71-72	.0	.0	.0	.0	.0	.0	4.0	T	T	T	.0	.0	4.0					
72-73	.0	.0	.0	.0	T	.0	.0	T	.0	.0	.0	.0	.0					
73-74	.0	.0	.0	.0	.0	.0	T	.0	.0	.0	.0	.0	.0					
SUM	.0	.0	.0	.0	.0	7.0	20.9	14.7	6.0	.0	.0	.0	40.3					

E AMOUNT IS WHOLLY OR PARTLY ESTIMATED.

T TRACE, AN AMOUNT TOO SMALL TO MEASURE.

M ONE OR MORE DAYS OF RECORD MISSING; IF AVERAGE VALUE IS ENTERED, LESS THAN 10 DAYS RECORD IS MISSING.

D WATER EQUIVALENT OF SNOWFALL WHOLLY OR PARTLY ESTIMATED.

MONTHLY NORMALS OF TEMPERATURE, PRECIPITATION AND HEATING AND COOLING DEGREE DAYS (1941-70)												
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
TEMPERATURE	44.6	47.8	54.5	65.1	72.8	79.9	82.0	81.2	75.1	64.8	53.5	46.0
PRECIPITATION	4.87	5.06	3.83	5.15	4.31	3.31	4.14	2.99	3.24	2.98	4.38	5.28
HEATING DEGREE DAY	632	489	353	77	9	0	0	0	106	349	580	2598
COOLING DEGREE DAY	0	8	28	80	231	447	927	502	306	103	0	2232

Fig. 42c Climatological summary for Greenwood, MS, from the series, "Climatography of the U.S. No. 20

EVAPORATION MAPS FOR THE UNITED STATES
Hydrologic Investigations Section, Hydrologic Services Division,
U. S. Weather Bureau, Washington, D. C.

Since evaporation inevitably extracts a portion of the gross water supply to a reservoir, the estimation of this loss is an important factor in reservoir design. In arid regions, the evaporation loss actually imposes a ceiling on the water supply obtainable through regulation. Speaking of storage on the main stem of the Colorado River, Langbein [30] states that "The gain in regulation to be achieved by increasing the present 29 million acre-feet to nearly 50 million acre-feet of capacity appears to be largely offset by a corresponding increase in evaporation."

In the final stages, the design of major storage projects requires detailed study of all data available, including observations made at the proposed reservoir sites. However, generalized estimates of free-water evaporation are invaluable in preliminary design studies of major projects, and are often fully adequate for the design of lesser projects. The maps presented herein have been prepared to serve these purposes, primarily, but they should be of value in other studies. For example, free-water evaporation [Figure 44] is a good index to potential evapotranspiration, or consumptive use, and the pan coefficient [Figure 45] is indicative of an aspect of climate. If solar radiation, wind, dew point, and air temperature are such that water in an exposed Class A pan is warmer than the air, the coefficient is greater than 0.7, and vice versa.

In 1942, A. F. Meyer [31] published a map comparable to that in Figure 44, and in the following year R. E. Horton [32] published a map of Class A pan evaporation similar to Figure 43. Subsequent to 1942, there has been a substantial increase in the Class A pan station network and significant progress in the development of techniques for estimating lake evaporation. However, the maps prepared by Horton and Meyer were carefully studied in the preparation of the new series -- any pronounced differences are considered to be reasonably substantiated by data now available.

Figure 45 shows the ratio of annual lake evaporation to that from the Class A pan. It can be used to estimate free-water evaporation for any site for which representative pan data are available. Figure 46 has been included to assist in the extrapolation of seasonal pan evaporation data to annual values, as well as to provide an indication of the seasonal distribution of evaporation from a shallow free-water body. Figure 47 shows the variability of pan evaporation, year-to-year, and can be used to estimate the frequency distribution of annual lake evaporation. The correct interpretation and use of these plates are discussed later.

METHODS FOR COMPUTING EVAPORATION - - The various methods for computing pan and lake evaporation are described in the Lake Hefner [33] and Lake Mead [34] Water-Loss Investigations Reports, and in Weather Bureau Research Paper No. 38 [35]. There are four generally accepted methods of computing lake evaporation: (a) water budget, (b) energy budget, (c) mass transfer, and (d) lake-to-pan relations. Very few reliable water-budget estimates are available because small errors in volume of inflow and outflow usually result in large errors in the residual evaporation value. The energy-budget approach requires such elaborate instrumentation that it is only feasible for special investigations. The mass-transfer method requires observations of lake surface-water temperature, dew point, and wind movement which are available for only a very few reservoirs. Methods (a), (b), and (c) are only applicable for existing lakes and reservoirs, and cannot be used in the design phase.

The few lake-evaporation determinations that have been made using water-budget, energy-budget, and mass-transfer methods were used in preparing Figs. 44-45. However, from a practical point of view, the lake-evaporation map is based essentially on pan evaporation and related meteorological data collected at Class A evaporation and first-order synoptic stations.

DEVELOPMENT OF MAPS - - The description of the development of the maps is given in Weather Bureau Technical Paper No. 37 "Evaporation Maps for the United States."

INTERPRETATION, USE, AND LIMITATIONS OF MAPS - - Although the utility of the derived maps hinges largely on their reliability, it is virtually impossible to make any meaningful generalizations in this respect. In deriving Figures 43-45, all available pertinent data were utilized to the greatest extent feasible with present-day knowledge of the relationships involved. It can be reasonably assumed, therefore, that the maps provide the most accurate generalized estimates yet available. The reliability of the maps is obviously poorer in the areas of high relief than in the plains region, and the density of the observation network is an important factor throughout.

It is known that some of the data collected over the years are from sheltered sites which are not representative. Through subjective evaluation of the station descriptions and wind data, an attempt was made to derive pan evaporation and coefficient maps indicative of a representative exposure, reasonably free of obstructions to wind and sunshine. Variations in the data were smoothed to a considerable extent, and it is entirely possible that the true areal variation in evaporation exceeds that shown on the maps. For example, a pan or small reservoir located in a canyon of northerly orientation and partially shielded from the sun would experience considerably less evaporation than indicated by the maps.

The effect of topography has been taken into account only in a general way, except where the data provided definite indications. Thus, it will be noted that the isopleths tend to follow closely the topographic features in some portions of the maps while the resemblance is more casual in other areas. Both Class A pan and lake evaporation were assumed to decrease with elevation however, the decrease assumed for lake evaporation is less. With an increase in elevation, dew point and air temperatures tend to decrease, while wind movement usually increases. Solar radiation, on the other hand, increases upslope during cloudless days and may otherwise increase or decrease depending on the variation of cloudiness with elevation. There are but few reliable observations of the variation of all these factors up mountain slopes, but it is probable that the effect of these changes is less for lake evaporation than for pan evaporation.

There is good reason to expect that Figure 46, showing seasonal distribution of pan evaporation, is more reliable than any other map in the series. Fig. 47, on the other hand, is based on a sparse network, and time trends resulting from changes in site, exposure, etc., may have caused some bias in the derived values of standard deviation. Data which were obviously inconsistent were eliminated from the analysis, but any undetected inconsistencies result in values which tend to be too high. Even so, any bias in the final, smoothed isopleths should be small.

The use of Figs. 43-47 is self-evident in most respects and need not be considered further here. Certain limitations and less obvious features are discussed in the following paragraphs.

Figs. 43, 44 and 45. Unless the user has at hand pan-evaporation data not considered in the development of this series of maps, average annual lake evaporation can be taken directly from Figure 44. The value so determined will also suffice if pan-evaporation data collected at the site substantiate that given by Figure 43. If the pan evaporation at the site exceeds that given by Fig. 43, application of the pan coefficient (Figure 45) will probably provide a better estimate of lake evaporation than that given by Figure 44. If, on the other hand, observed pan evaporation is less than that given by Figure 43, a value of lake evaporation less than given by Figure 44 should be accepted only after it has been determined that the pan site is reasonably free of obstructions to wind and sunshine. This is to say that pan evaporation and the pan coefficient are both dependent upon exposure.

It should be emphasized that values of free-water evaporation given by Fig. 44 (or Figs. 43 and 45) assume that there is no net advection (heat content of inflow less outflow) over a long period of time. The mean annual advection is usually small and can be neglected, but this is not always the case. It was found at Lake Mead, for example, that advection results in a 5-inch increase in mean annual evaporation. If the advection term is appreciable, adjustment should be made as discussed in references [34] and [35].

Figure 46. The Class A pans are not in operation during the winter months over much of the country because of freezing weather. Fig. 46 provides means of estimating average annual evaporation from that observed during the open season, May through October. When used in conjunction with Fig. 43, it also provides a means of estimating average growing-season evaporation (Class A pan) which is so important in some studies.

Although the seasonal ratios of Fig. 46 are based on Class A pan data, it is believed that they are equally applicable to free-water evaporation for shallow lakes. The ratios based on monthly computed lake evaporation for the first-order stations showed no significant deviation from those based on the pan values. It should be emphasized that the seasonal ratios can be applied to annual lake evaporation only in case of shallow lakes where energy storage can be ignored. In deep lakes, the energy storage becomes an important factor in determining seasonal or monthly evaporation. For example, at Lake Mead the maximum lake evaporation occurs in August, but maximum Class A pan evaporation is observed in June; for Lake Ontario, the maximum lake evaporation is in September, and maximum pan evaporation in July. Corrections can be made for changes in energy storage and heat advection into or out of the lake in the manner described in references [34] and [35].

Figure 47. The standard deviation of annual Class A pan evaporation can be obtained for any selected site directly from Fig. 47. If the annual pan coefficient were constant, year-to-year, then the standard deviation of lake evaporation would be the product of that for pan evaporation and the pan coefficient. Because of variation in the annual pan coefficient, the standard deviation computed in this manner may be a few percent too low. Since the values given by Figure 47 are probably biased on the high side (discussed previously), the two possible errors tend to compensate.

Having obtained the mean and standard deviation, the frequency distribution of annual lake (or pan) evaporation can be derived, assuming the data are normally distributed. If it is further assumed that the annual evaporation totals occurring in successive years are independent, the frequency distribution of n-year evaporation can also be derived.

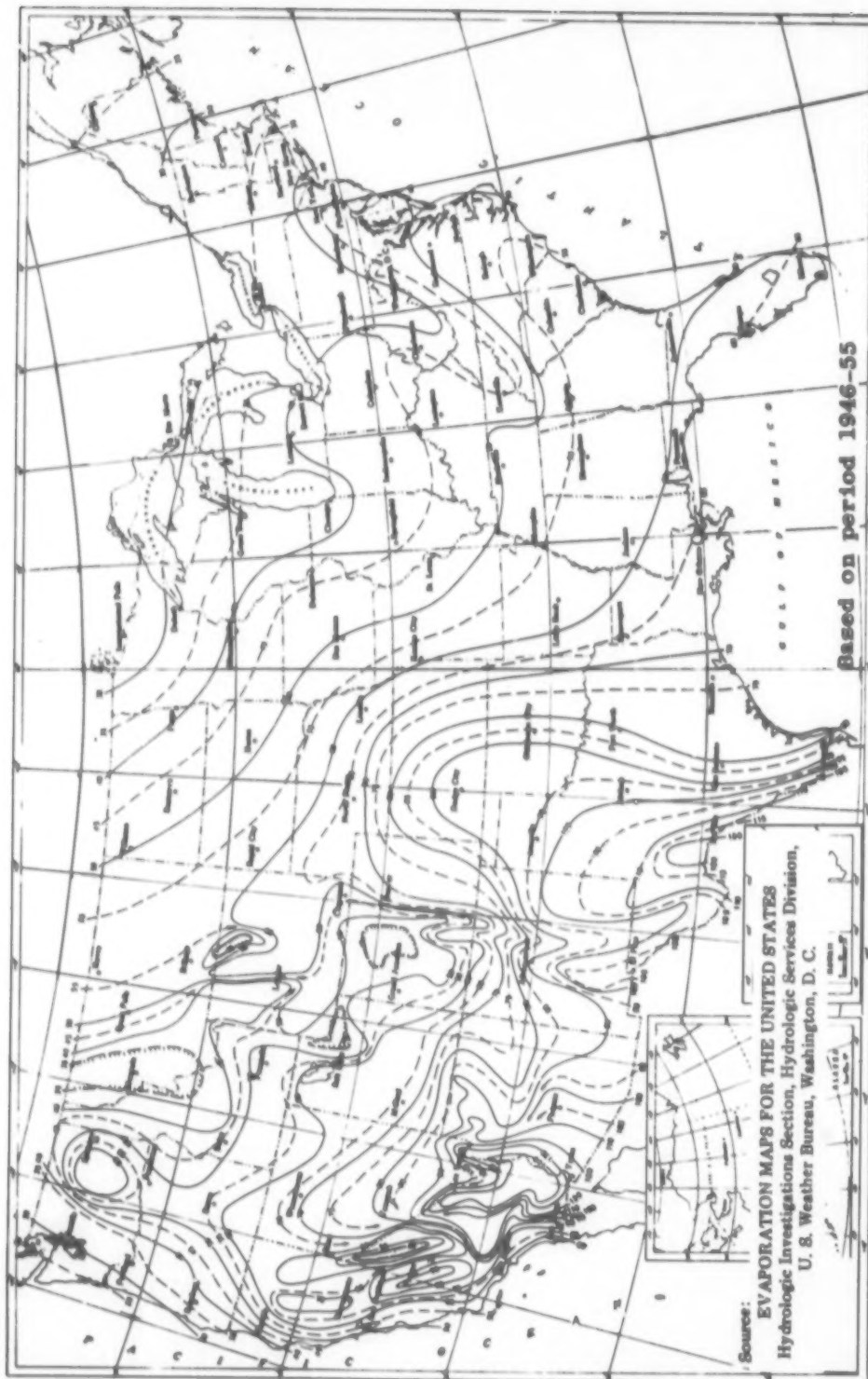


Fig. 43 Mean annual class A pan evaporation (in inches)

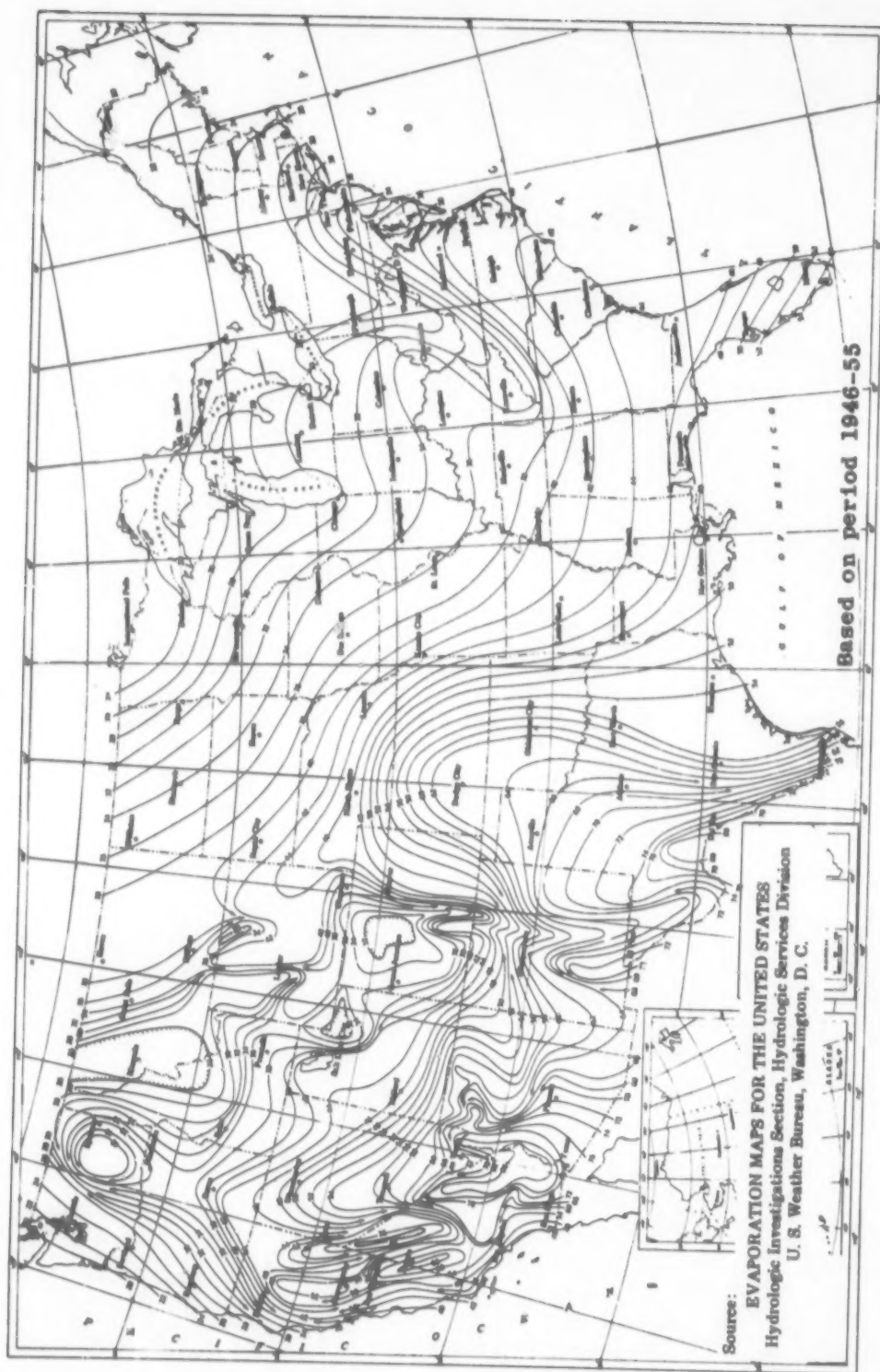


Fig. 44 Mean annual lake evaporation (in inches)

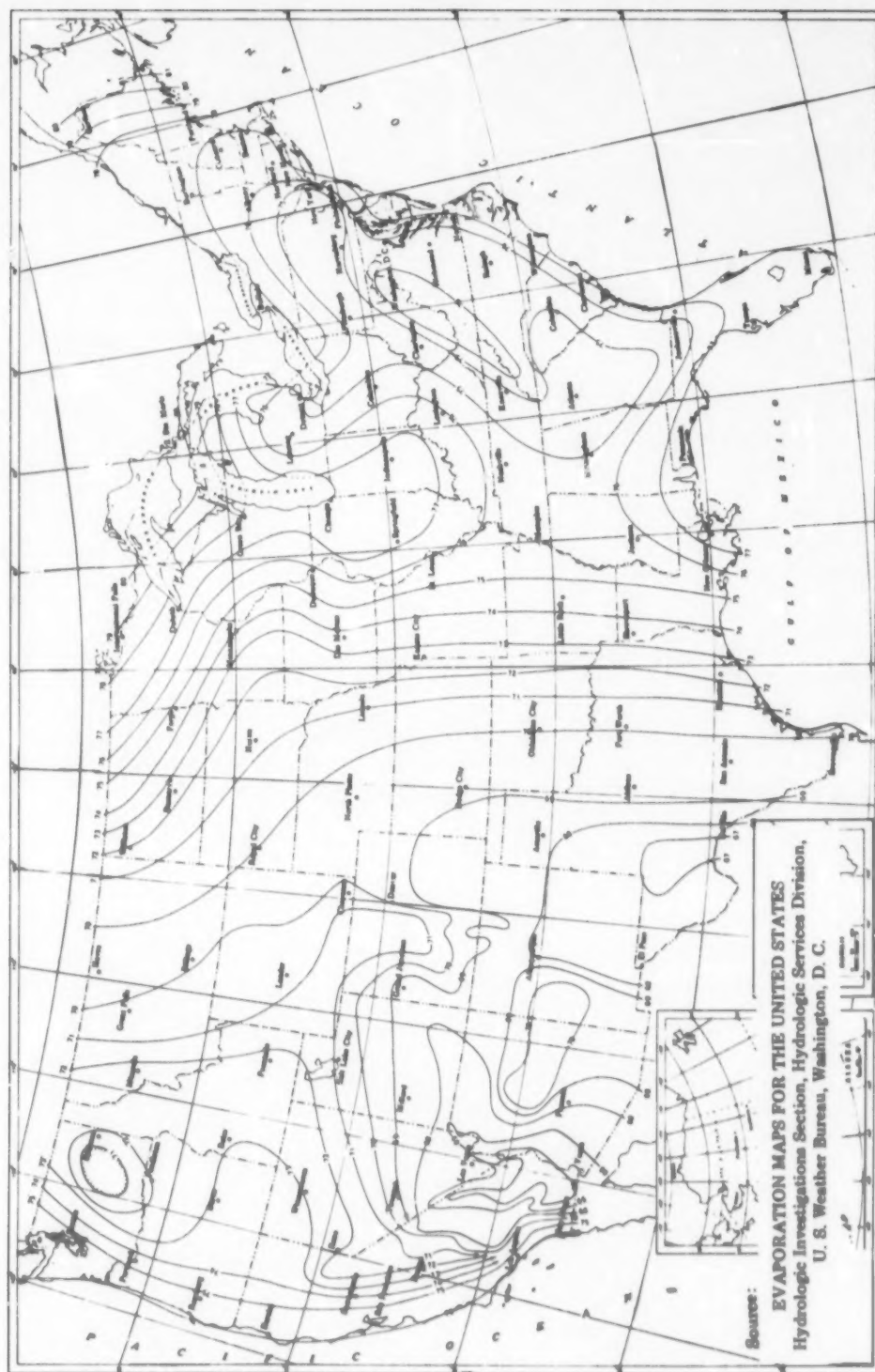


Fig. 45 Mean annual class A pan coefficient (in percent)

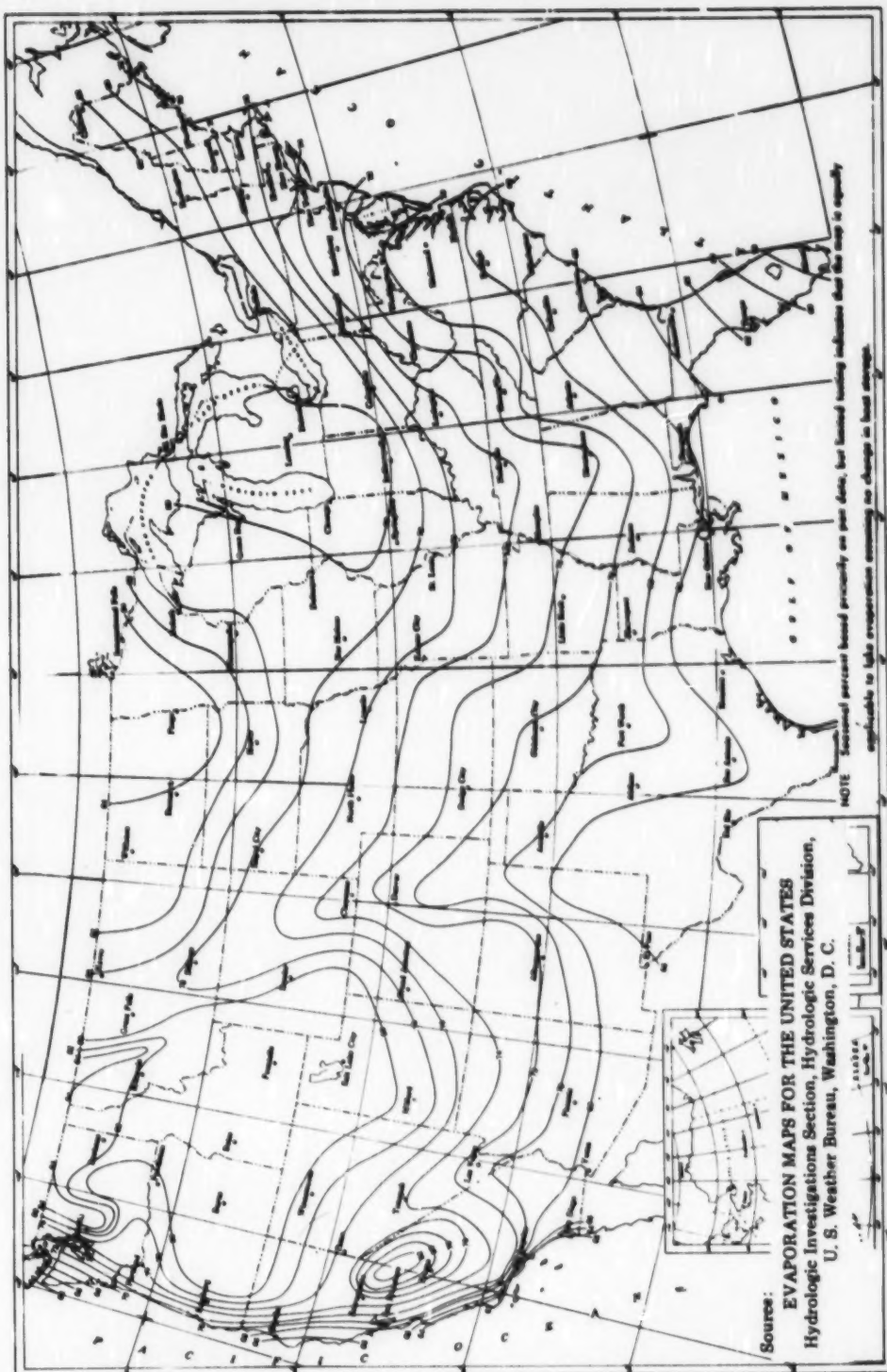


Fig. 46 Mean May-October evaporation in percent of annual

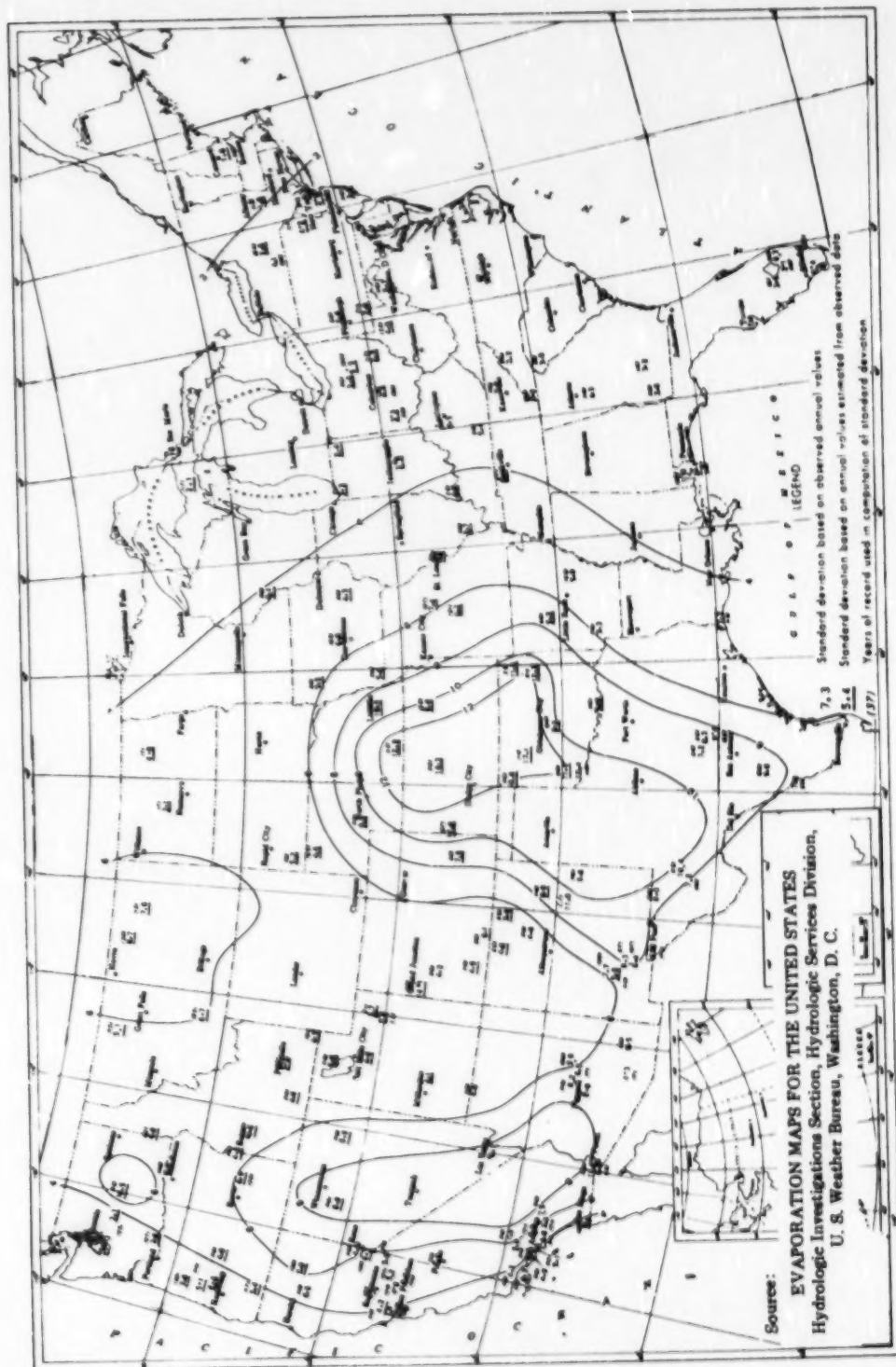


Fig. 47 Standard deviation of annual class A pan evaporation (in inches)

APPENDIX C.

REQUESTS FOR SERVICES

The National Climatic Center may furnish special services for private clients under authority of an Act of Congress which permits the NCC to provide services at the expense of the requester. The amount the requester is charged in all cases is intended solely to defray the expenses incurred by the Government in satisfying his specific requirements to the best of its ability.

Unit costs have been established for reproduction or processing of data. The product can be in various forms, such as copies of microfilm, magnetic tapes, computer output in the form of tabulations, or other types of material. In the case of the programs discussed in this report, the station record must be serially complete and readily available in the NCC tape library. A day or two of missing record during a month is acceptable over the 20 to 25 year record, but care must be exercised to avoid processing stations with excessive missing record. Upon establishing that an adequate data base exists and costs agreed on, authorization for the NCC to proceed with the work may be made by letter or telephone. A copy of the product will be forwarded, usually within 3 to 4 weeks, along with an invoice. No advance payment is necessary, although private users who have a continuing need for climatological services may make advance deposits to cover the cost of their requirements as they arise. This procedure eliminates the need for separate invoices upon completion of each request. Further information about the programs may be obtained by contacting the Statistical Climatology Branch, National Climatic Center, Federal Building, Asheville, North Carolina 28801 (telephone 704-258-2850, ext. 319).